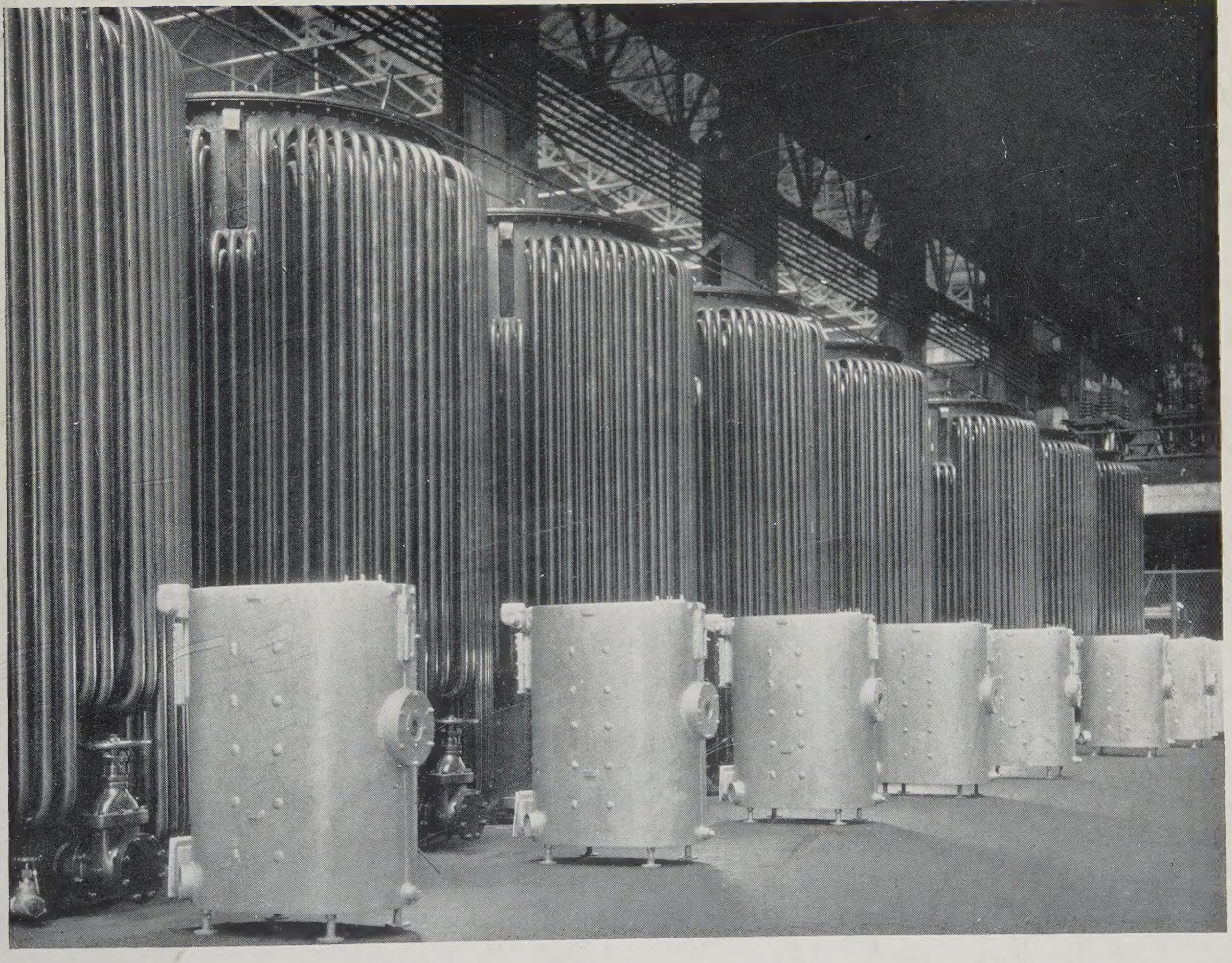
Electrical Engineering

April
1933



Published Monthly by the
American Institute of Electrical Engineers

North Eastern District Meeting, Schenectady, N. Y., May 10-12, 1933

Future Meetings of the American Institute of Electrical Engineers

Place	Date	Nature	Manuscript Closing Date
Schenectady, N. Y.	May 10-12, 1933	District Meeting	(Closed)
Chicago, Ill.	June 26-30, 1933	Summer Convention	(Closed)
Salt Lake City, Utah	Sept. 4-8, 1933	Pacific Coast Convention	June 4, 1933

NOTE: Members who are contemplating submitting papers for presentation at any of the above meetings should communicate promptly with Institute headquarters, 33 West 39th Street, New York, N. Y., so that such papers may be docketed for consideration by the technical program committee, which formulates programs for all meetings several months in advance. Upon receipt of this notification, Institute headquarters will mail to each prospective author important and helpful information explaining the Institute's rules relating to the preparation of manuscript and illustrations.

Future Meetings of Other Technical Organizations

Society and Nature of Meeting	Place	Date	Correspondent
American Institute of Mining Engineers, regional meeting	Chicago, Ill.	June 26–30	A. B. Parsons, Secy., 29 West 39th St., New York, N. Y.
American Oil Burner Association	Chicago, Ill.	June 12–16	H. F. Tapp, Secy., 342 Madison Ave., New York, N. Y.
American Physical Society	Washington, D. C.	Apr. 27–29	W. L. Severinghaus, Secy., Columbia Univ., New York, N. Y.
American Physical Society, Pacific Coast meeting	Salt Lake City, Utah	June 15–16	L. B. Loeb, Pacific Coast Secy., Univ. of Calif., Berkeley, Calif.
American Physical Society	Chicago, Ill.	June 19–24	W. L. Severinghaus, Secy., Columbia Univ., New York, N. Y.
American Society for Testing Materials	Chicago, Ill.	June 26–30	Am. Soc. for Testing Mtls., Phila., Pa.
American Society of Civil Engineers	Chicago, Ill.	June 27–30	G. T. Seabury, Secy., 29 West 39th St., New York, N. Y.
American Society of Mechanical Engineers	Chicago, Ill.	June 26–30	C. W. Rice, Secy., 29 West 39th St., New York, N. Y.
American Transit Association, annual convention	Chicago, Ill.	Sept. 25–30	G. C. Hecker, Secy., 292 Madison Ave., New York, N. Y.
Edison Electric Institute	Chicago, Ill.	June 5–8	B. F. Weadock, 420 Lexington Ave., New York, N. Y.
Electrochemical Society	Montreal, Que.	May 11–13	C. G. Fink, Columbia Univ., New York, N. Y.
Maryland Utilities Association	Baltimore, Md.	April 21	D. E. Kinnear, 803 Court Square Bldg., Baltimore, Md.
Missouri Association of Public Utilities	Excelsior Springs, Mo.	April 27–29	N. R. Beagle, 101 West High St., Jefferson City, Mo.
National Fire Protection Association	Milwaukee, Wis.	May 29–June 1	A. R. Small, Chmn., 109 Leonard St., New York, N. Y.
Society for the Promotion of Engg Education	Chicago, Ill.	June 27–30	F. L. Bishop, Secy., Univ. of Pittsburgh, Pa.

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This Month—

Front Cover

A row of completed all-welded boilers for General Electric oil furnaces dwarfed by giant 132-kv 25-cycle special railway transformer tanks, also welded. Approximately $^1/_2$ million inches of welding is done each week in producing these boilers. Those attending the A.I.E.E. North Eastern District meeting in Schenectady, N. Y., May 10–12, 1933, will have an opportunity to see some of these furnaces in the course of production.

TESTS SHOW that electric power cables connected to overhead lines may be subjected to traveling waves, the voltage to sheath depending upon the nature and location of the sheath grounds. *p. 238–9*

A REACTANCE relay has been developed for electric power transmission lines which uses the induction dynamometer principle for the production of torque. This relay is said to operate in the order of one cycle. *p. 248–52*

WIND AND SLEET, both arch enemies of overhead lines, when combined sometimes cause the conductors to vibrate with extremely large amplitudes. An analysis of this type of vibration shows that it is caused by aerodynamic instability. *p. 240–2*

A LARGE eastern power system has interconnected the primary lightning arrester ground with the grounded secondary neutral on many of its transformers. Operating experience has been such that it is planned to extend the use of this interconnection. *p. 229–32*

SOME of the more important factors in transmission line design are outlined in a report prepared by an A.I.E.E. subcommittee. *p. 243*

NON-LINEAR circuits of both the series and parallel type have been found to be readily adaptable to a-c relays. These relays are highly sensitive to small changes in voltage and current, and are sturdy mechanically. *p. 244–6*

A NOTED telephone engineer and past-president of the Institute gives his ideas concerning engineers and present economic conditions. *p. 257–8*

THE Committee on Welded Rail Joints on which the A.I.E.E. is represented by D. D. Ewing (F'20) recently issued its final report. *p. 277–9*

INSTITUTE members and readers of ELECTRICAL ENGINEERING continue to express themselves on various subjects through the "Letters to the Editor" columns. *p. 279–81*

SUMMARIZED discussions of papers presented at the winter convention are continued in this issue. Subjects covered include rectifiers, insulation coordination, and lightning. *p. 274–7*

PARALLEL type electronic tube inverters for changing direct to alternating current already have been used to supply a-c radio sets from d-c sources, and give promise of becoming of further importance. *p. 253–6*

ECONOMIC conditions such as those prevailing at the present time always provoke much discussion on private versus public enterprises. At a recent meeting of the Advertising Club of New York City, this question was discussed in the light of present conditions by 2 men well known in their respective fields. *p. 234–7*

A SYMPOSIUM on reactive power is to be conducted as a feature of the Institute's North Eastern District meeting to be held in Schenectady, N. Y., May 10–12, 1933. Discussion on the various factors involved in measuring and defining reactive power are invited from members. An introduction to this symposium and 2 of the papers are included in this issue. *p. 259–70*

AERONAUTICS, air conditioning, and reactive power are 3 interesting subjects on which technical sessions of the Institute's North Eastern District meeting, Schenectady, N. Y., May 10–12, 1933, will be held. A fourth session will be on selected subjects. The facilities of the General Electric research laboratories and works will be available for inspection and as sources of entertainment as well. *p. 271–3*

Cosmic Rays—
What Physicists Have Learned About Them

"Cosmic rays" is the name applied to the ultimate cause of that part of the ionization of the air that cannot be ascribed to any known agencies. In spite of this prosaic definition, however, seldom if ever has there been a subject of research in physics in which intrinsic importance and romantic associations so happily are combined. In view of the fundamental importance of cosmic ray research, in this article is given a review of studies made in this engrossing field from the time of early experiments with the gold leaf electroscope down to the present day of many and conflicting theories and speculations.

By
KARL K. DARROW
ASSOCIATE A.I.E.E.
Bell Telephone Laboratories,
New York, N. Y.

THE DEVELOPMENT of modern physics is carried on mostly in placid and sequestered fashion, deep in laboratory buildings or in the formidable pages of the scientific journals; but now and then it is enlivened by a sudden blazing-up of general, almost of universal interest in some special topic of research. The latest of physical enterprises to enjoy the spotlight of public attention is the study of cosmic rays. "Enjoy," of course, is a word of which some physicists will not approve; there is a feeling (understandable enough) that the proper time for publishing a new conquest to the world at large is not till it has been thoroughly explored, organized, and settled—not, in other words, until the epoch of research has ended. But even if it were possible, it would be pitiful to conceal from the public the exhilarating spectacle of science in the phase of rapid growth, of flux, of change, of controversy even. Perhaps, indeed, if public attention were drawn oftener to that spectacle, it would help to weaken the all-too-common impression that science is a system of fixed dogmas expressed in immutable language, and strengthen the much more desirable idea that science itself must evolve like the race which learns it, restates it, enlarges it and hands it on transformed from generation to generation.

Seldom if ever has there been a subject of research in physics, in which intrinsic importance and romantic associations were combined so happily as they are in cosmic rays. Almost every one knows of the wonderful journeys of the investigators into the farthest quarters of earth and air and sea; many know a little of the grandiose speculations as to the origin of the rays; least of all, perhaps, is commonly known about the extreme minuteness of the phenomena by which the radiation is revealed. Cosmic rays are detected because, and only because, they detach electrons from the molecules of air. Close to sea level, where laboratories mostly are erected, there are about 3×10^{19} molecules in a cubic centimeter of air. Out of these *30 millions of millions of millions*, the rays in every second of time detach electrons (on the average) from *2 or 3*. This is what must be detected, and not only detected, but measured. Higher up in the sky the effect is several-fold more considerable, but what are hundreds or even thousands among millions of millions of millions?

Now any physicist, confronted with the problem of detecting a few electrons set free in a second in a cubic centimeter of air, would want to attack it in the best possible laboratory, in a room well guarded against vibrations, shocks, temperature changes, disturbances of every kind. He would want several months, if not years, to set up the apparatus in its permanent place and get it working. Yet it is necessary, or at any rate very desirable, to measure cosmic rays in the arctic regions, and the tropics, and deep down in mines, and high up on peaks, and even higher than the highest mountain in the world; hence the physicist must pack up his apparatus and take it with him to all sorts of places not designed by Nature for experiments of precision. Indeed he will want to measure in places where no man can reach; and his machine must be able to go to those places by itself, take its own readings, record them, and bring them back to him. Imagine the problem of making apparatus delicate enough to measure an effect so small, skillful enough to record its own measurements, and rugged enough to withstand the vicissitudes of travel and aviation!

The apparatus must be considered closely, for these rays are best defined by describing the ways in which they are measured. Indeed some physicists maintain that everything with which physics has to do is best defined, if not exclusively defined, by describing how it is measured; whether general or not, this rule certainly is valid for cosmic radiation.

The Electroscope in Early Experiments

The predecessor of all cosmic ray experiments is the simple and familiar demonstration with the gold leaf electroscope—the twin ribbons of gold foil hanging side by side from a metal clamp affixed to an

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insulating knob, which spring apart at the moment a charge is imparted to the clamp, because the charge distributes itself over both of the ribbons of gold, and each repels the other. In Fig. 1 is shown a modification of this device, which actually has been used (by Millikan) in cosmic ray research; the ribbons of gold are replaced by fibers of quartz connected end to end, which bow outward when a charge is imparted to them.

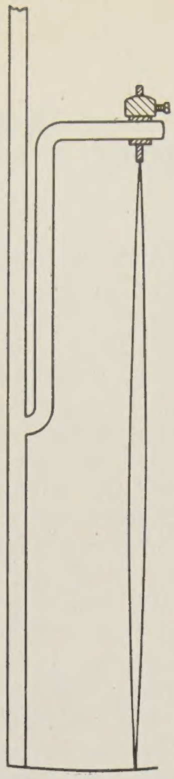


Fig. 1. Two-fiber electroscope (Millikan)

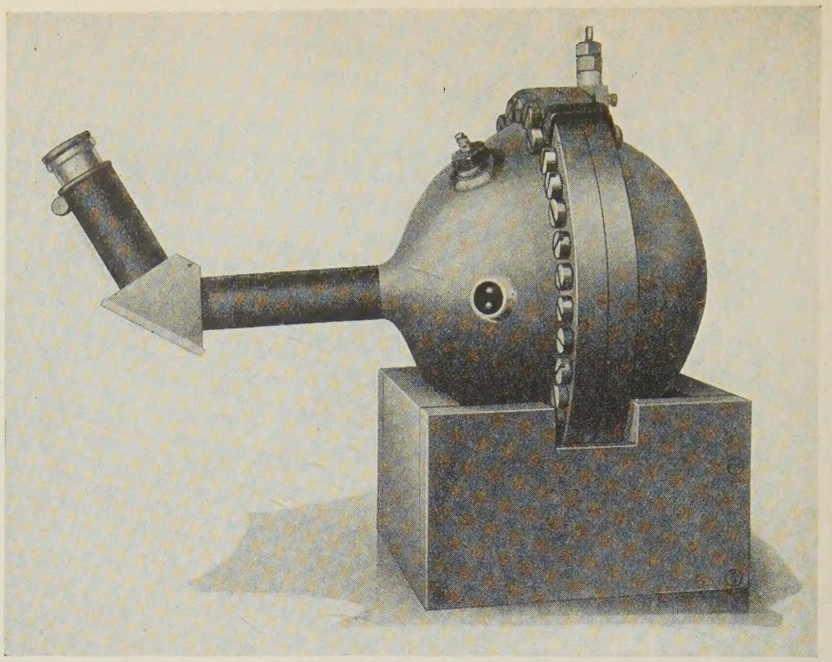


Fig. 2. Ionization chamber for subaqueous measurements (Millikan)

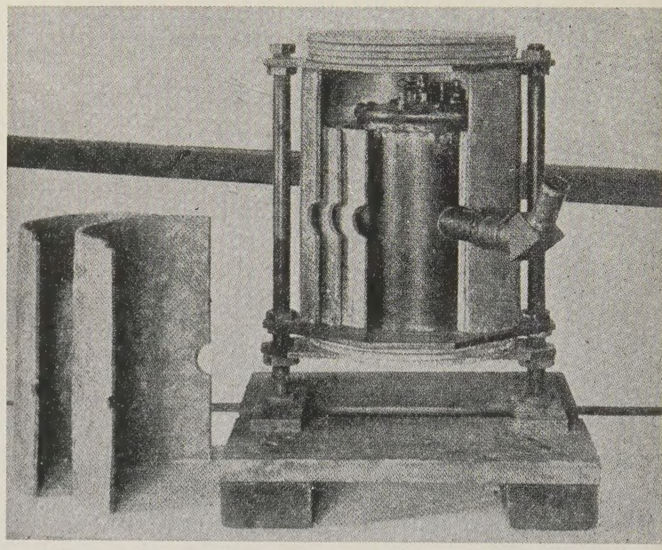


Fig. 3. Ionization chamber with removable lead screens (Millikan)

Now when the gold leaves or the quartz fibers are left to themselves after the moment of charging, they gradually come together; the charge gradually disappears. In the early days of physics it was thought that the electricity was escaping through the insulators, which are not quite perfect barriers to current. This is indeed a partial explanation, but not a total one; the leak through the insulators does not account for the whole of the escape, *there is also conduction through the air.* Coulomb, whose name is commemorated in the customary unit of electric charge, is said to have been the first to prove this, and thus he is a forerunner of the study of cosmic rays.

Eventually it was found out that the conduction through the air may be enhanced enormously by the rays from radioactive substances, or from an X-ray tube. There is a favorite and ever-startling trick of lecturers, to walk up to an electroscope while carrying a bit of radium, and let the audience see how the gold leaves hastily fall together. Then it was found that the conduction through ordinary air is largely due to the rays from radioactive bodies floating around on particles of dust, or embedded in the nearby ground. A great part of modern physics is derived from these discoveries, and any one who undertakes to tell the story is tempted almost irresistibly to wander far afield; but it is necessary to be resolute, and to press straight on to the conclusion. Air is conductive because its molecules are being ionized—because, that is to say, electrons continually are being detached from its neutral molecules, themselves wandering off through the gas as negative ions and leaving the residues of the molecules to wander as positive ions.

Consider once more the gold leaves or the quartz fibers surrounded by air and charged with a charge which, for definiteness, is assumed to be negative. When a nearby molecule is ionized, the resulting positive ion is drawn to the fibers, and on reaching them it neutralizes itself by removing an electron from them, thus diminishing their charge by the amount denoted by the well-known symbol e. Its function now is finished; if the fibers continue to lose charge, it is because other molecules are being ionized, one after another. The rate at which the charge disappears, measured in terms of e, is thus the rate at which molecules are being ionized in those parts of the air from which the ions can reach the fibers. In cosmic ray research a certain amount of air (or of some other gas) is enclosed in a metal shell more or less resembling a bomb (Figs. 2 and 3); this "ionization chamber," as it is called, is so proportioned and the voltages so adjusted that all of the

ions of proper sign that are formed within it reach the fibers, or the electrode which does duty for them. (Lately, serious doubts have arisen as to whether this condition actually was fulfilled in some cases in which it was thought to be.)

Cosmic Rays Defined

It has just been implied that a great deal of this ionization is due to rays from radioactive substances dispersed through the air and the earth. Could it *all* thus be explained? This is the fundamental question in cosmic ray research; for cosmic rays are *by definition* the cause of that part of the ionization which is demonstrably not produced by any other known agency whatever. They are the cause of the residue, of what is left over after everything otherwise accountable has been accounted for. It is not sufficient to measure ionization; it is necessary to be sure how great a part of what is measured can be explained without invoking cosmic rays.

Much of the strangeness, much of the rare and romantic quality of cosmic ray research is due to this condition. One may surround the ionization chamber with huge quantities of lead, for armor-plating of this metal 10 cm thick will keep out nearly all of the rays from radioactive bodies; but it will be very heavy, and hence research along these l nes is for people with strong muscles. One may take the apparatus onto an ice-floe over a lake or a sea (physicists did this near Toronto, Can., as long as 30 years ago) or sink it into a pond; when a full meter of water separates it from the nearest solid earth, it is screened as well from the radioactivity of the ground as though 10 cm of lead surrounded it. But is there not radioactivity to be feared in the waters of oceans or lakes, derived as they are from currents that have seeped through the earth? Millikan, to avoid this danger, went to the heights of the Sierras and chose ponds that received their water entirely from fallen snow; other physicists in Switzerland have dug holes into glacier ice, and encamped there with their instruments; Regener found that he could measure underneath the surface of the Lake of Constance without being troubled by radioactive bodies.

It is interesting here to pause and look at some of Regener's records, that is to say, the records which his instrument made for him in the depths of the lake and brought back for him to survey; one set of these is reproduced in Fig. 4. The vertical lines that appear in such numbers in that illustration are photographs of the fiber of his electroscope (a single string instead of the 2-fiber device shown in Fig. 1) taken on a film inside of the ionization chamber itself, by flashes of light which a timing-device set off at intervals of an hour. On the topmost band the image is shifted far from one hour to the next; the fiber is moving rapidly, the charge is leaking rapidly away from it, the air in the chamber is being ionized at a rapid rate; the apparatus was 32 m below the surface of the lake. The next band below the top corresponds to a depth of 78 m; the images are closer together, the fiber is losing its charge more slowly, the ionization is less, the ioniz ng agent is feebler. At 173 m the ionizing agent is feebler yet, at 231 m very weak indeed; most of the shift appearing in the lowest band is due to mere leakage through imperfect insulators, or perhaps to radioactivity in the walls of the chamber itself (for which allowance must, and generally can, be made).

Regener plotted the strength of the ionization against the depth of the chamber below the surface

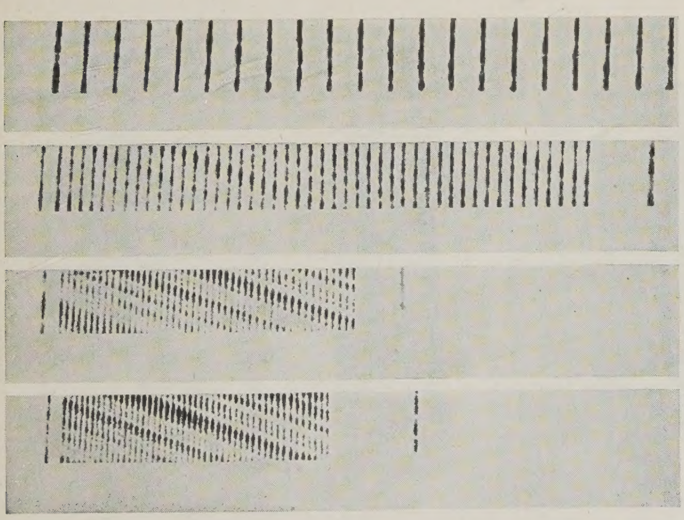


Fig. 4. Photographic records of electroscope fiber being slowly discharged by cosmic rays (Regener)

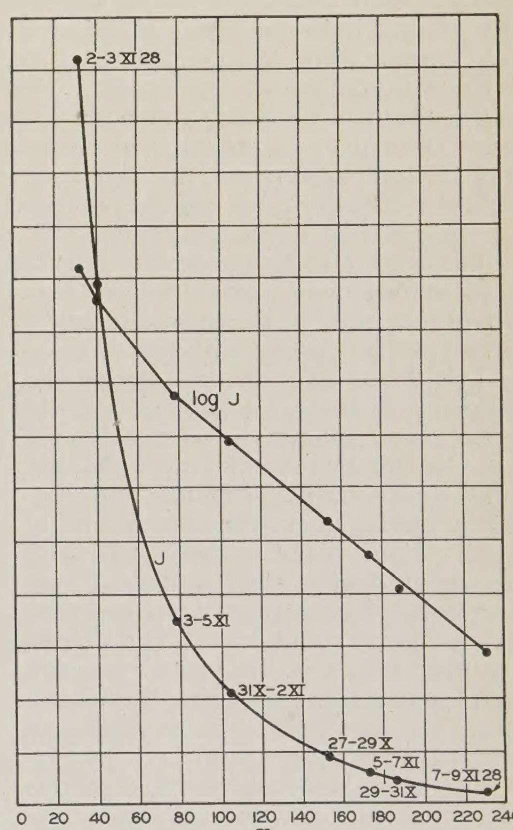


Fig. 5. Direct and logarithmic curves (latter corrected for radioactivity of chamber wall) of ionization *vs.* depth underwater (Regener)

of the lake, and Fig. 5 shows the relation. It suggests an ionizing agent coming from above into the water, being steadily weakened or absorbed as it descends, and yet so powerfully penetrating that an appreciable part still forges ahead past more than 200 m of water. No rays of any kind from radioactive bodies come anywhere near to this in power of penetration, in "hardness" as physicists frequently say. "Penetrating rays" was accordingly one of the earliest names applied to this agent, and many scientists must regret that it did not remain the only name; still, had the rays not been called "cosmic," it is likely enough that far fewer people would have been interested in them.

There also have been expeditions in which the apparatus sought, not the depths of the sea, but the heights of the sky. This recommended itself at first because, if enough air is put between the ionization chamber and the radioactive substances in the ground, the rays of these latter will be kept away as effectually as they would be by water or lead. True, it takes a good deal of air—half a mile—to be as effective a stop as a yard of water or 4 in. of lead. But even before the war, it was possible to ascend more than half a mile in a balloon; and several German physicists (Gockel, Bergwitz, Hess, Kolhörster) ventured themselves in flight. Their ionization chambers were not heavily walled with lead, and the rays of radioactive bodies could penetrate them. Accordingly, near the earth their readings were high, and declined at first as each balloon started upon its ascent. Had the radioactivity of the ground been the cause of all of the ionization, that decline must have continued until, at a height of half a mile or so, the readings vanished away. But instead of declining indefinitely, the ionization went through a minimum, and thereafter it rose—higher and higher—as the balloons continued to mount. Therefore, so ran the inference, there must be an ionizing agent pervading the whole of the atmosphere, the source of which the observers were approaching more and more closely as they climbed up into the sky. The study of cosmic rays commonly is said to have begun with this discovery.

The World War made a gap in the sequence of these researches, as it did in so many others; a rather extended gap, for interest in the rays did not fully revive until the middle twenties. Then, having made some mountain-top observations, Millikan decided to send apparatus higher than any man ever had flown, higher than it seemed that any man ever could fly. It had to take its own records of ionization, pressure and temperature, and bring them back intact; it also had to be as small and light as it possibly could be. In Fig. 6 are shown some photographs of this clever device, assembled and disassembled. At the right may be seen the barometer B, the thermometer T (a coiled spring that shortened as the temperature fell), the casing M of the electroscope fibers, and the vital parts of a watch that kept in motion a photographic film, on which the light of the sky imprinted images of the fibers, the thermometer coil, and the meniscus of the barometer. All of these went inside of the cylinder S_1, the size of which is shown by the 6-in. ruler at its right!

Apparatus Ascends 14 Miles

A pair of balloons bore the device aloft, until at a great height one of the 2 exploded, and the ionization chamber sank to the earth, yet so slowly, thanks to the buoyancy of the balloon surviving, that the records were not damaged in the landing. In the actual case, the chamber ascended $15^1/_2$ km over the plains of Texas, and came to earth again 80 miles away. Piccard was later to ascend still higher, taking along apparatus of 2 different types. No other man yet has approached this record, but Regener's apparatus has traveled higher even than Piccard's. In Fig. 7 it may be seen starting its ascent; it is enclosed in the strangely shaped box underneath. At the top are the 2 balloons (8 ft in diameter) while between the balloons and instrument case is a sort of parachute for limiting the speed. On this occasion (January 3, 1933) it ascended 14 miles, and reached a region where the pressure of the air is less than $^1/_{20}$ as great as at the surface of the earth.

Data of the recent flights, and of other ascensions lately directed by Millikan, but not yet published in detail, fit together admirably. Compton has plotted most of them, and in Fig. 8 is shown his graph including some of Regener's observations, some of Piccard's, some of the pre-war data of Kolhörster, and various measurements made on Andean, Alpine, and other peaks by Compton himself and his associates. Near the top of the curve—that is to say, at the tremendous heights which are the limit of the ultimate ascents of human beings and man-made apparatus—the effect of the cosmic rays on a gas in an ionization chamber is 100 times as great as it is at sea level. (In the actual atmosphere the ratio is not so high, because at the great altitudes the

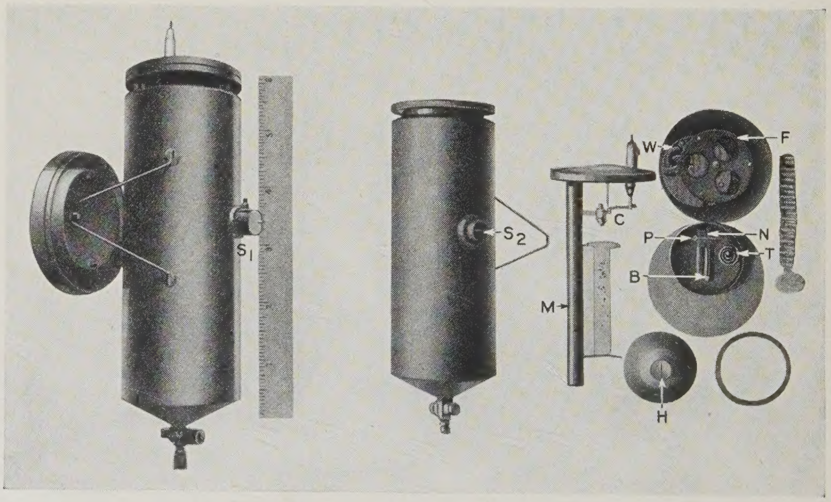


Fig. 6. Apparatus borne aloft by balloons for measuring cosmic rays in the upper air (Millikan)

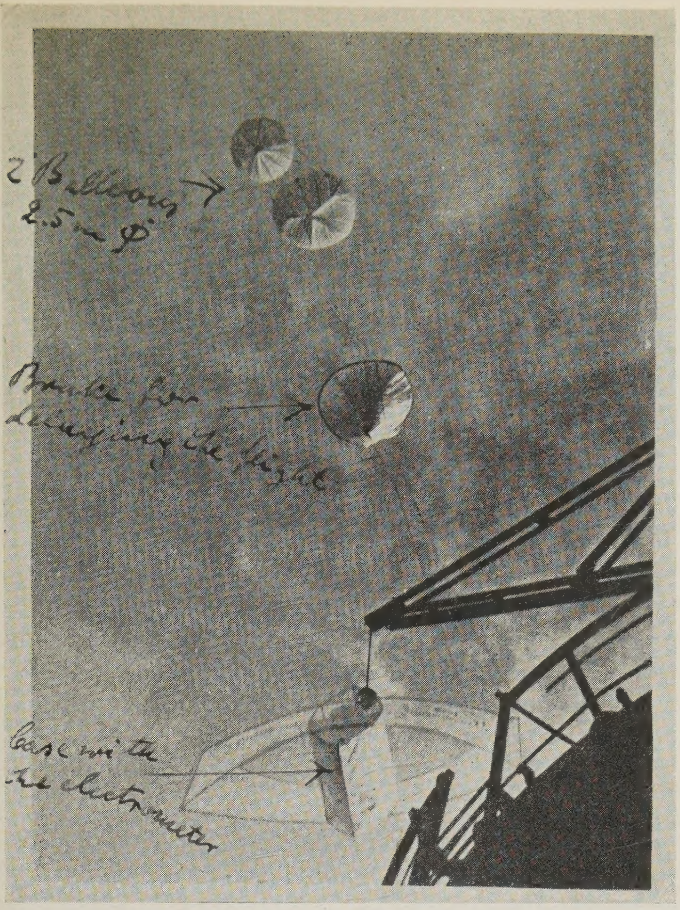


Fig. 7. Start of a recent balloon ascension of unaccompanied apparatus (Regener)

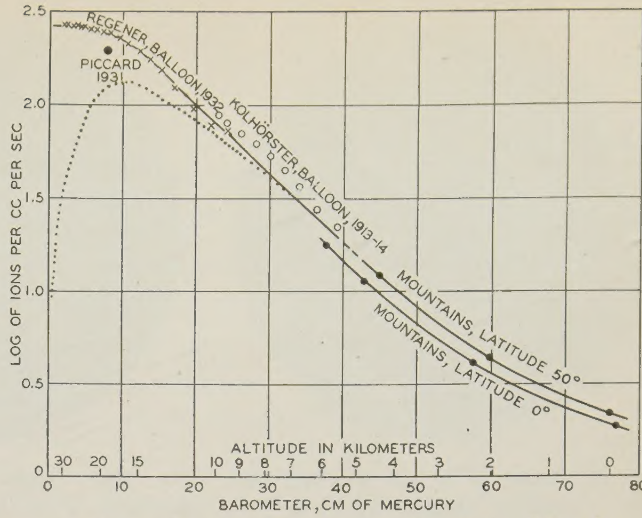


Fig. 8. Ionization plotted as a function of height above ground and pressure of atmosphere (Compton)

air is so much rarefied.) This disposes of the ancient idea that the rays proceed from the earth, and refers their origin to the outer universe or at least to the inaccessible reaches of the atmosphere where meteors flash and the aurora flares.

The trend of the curve of Fig. 8 is undoubtedly a sign of the nature of the rays, but a sign difficult to read. Fortunately there are 2 other kinds of apparatus that detect the cosmic rays, and the testimony of these 2 is wonderfully lucid and direct in regard to certain things, which from the readings of electroscopes could be deduced only with great trouble and little confidence. As stated previously, the ionization due to the cosmic rays at sea level amounts *on the average* to only 2 or 3 ions per second per cubic centimeter—say, 25,000 or thereabouts in a chamber of 10 liters capacity containing air at atmospheric pressure. It must not be inferred, however, that these 25,000 ion-pairs appear entirely at random, scattered irregularly all through the 10 liters of air and all through the second of time. On the contrary, these other methods show that the ionization occurs by sudden spurts or bursts; and one of them shows that each spurt is caused by the transit of a fast-flying corpuscle across the gas.

In Figs. 9, 10, and 11 are reproduced photographs taken by C. D. Anderson, a young collaborator of Millikan at Pasadena, Calif They display fine sharp lines, some curved, some straight. These lines are trails of mist, processions of water droplets often, though not always, too small and close together to be seen individually. Each droplet of water surrounds an ion; for an ion has the property of causing water vapor to condense and form a liquid sphere around itself. True, this property cannot be exercised except under special conditions; the air must be freed of dust and must be overladen or "supersaturated" with water vapor, and then it must be suddenly and sharply cooled to precisely the right degree. It is in a chamber, one wall of which can be caused to fall back very quickly through a predetermined distance, so that the air is cooled by expansion (whence the name "expansion method"). The opposite wall is of glass, and a brilliant light shines into the chamber so that whatever happens within can be photographed.

When the pictures in Figs. 9, 10, and 11 were taken, the gas had just expanded, and also an ionizing corpuscle had just traversed it, so that conditions were precisely right for the formation of droplets along the track which the corpuscle had pursued. Had the expansion happened a little too soon, there would have been no condensation; had it happened a little too late, the droplets would have formed a hazy cloud instead of a sharply marked line, for the ions would have dispersed in all directions from the points where they were formed. It is therefore by lucky coincidence between the moment of an expansion and the moment of passage of a cosmic ray corpuscle that such a picture is obtained. The machine is run by clockwork and a photograph taken at every expansion, and with a fairly large chamber one plate in 20 or 30 may show the image of a track.

One cannot deny that the ionization is due to flying corpuscles! They are proved as fully by these trails, as the existence of meteors by luminous linear trails in the evening sky. But this result does not solve the problems of cosmic rays; rather it gives definite form to some of the questions that must be asked.

In the first place, what are these corpuscles? It is practically certain that they are charged, for in many cases their paths obviously are curved in

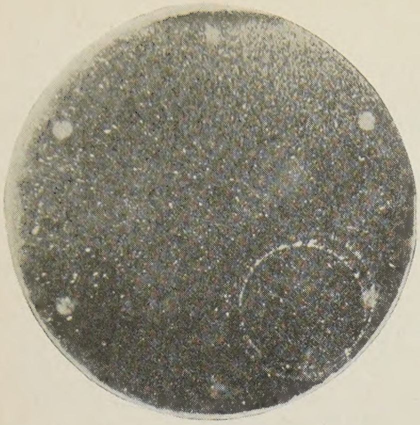


Fig. 9. Track of a fast electron (80 million electron-volts) (Anderson)

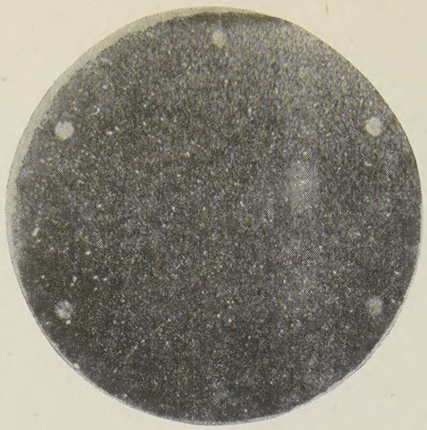


Fig. 10. Tracks of an electron and probably a proton diverging from a common point (Anderson)

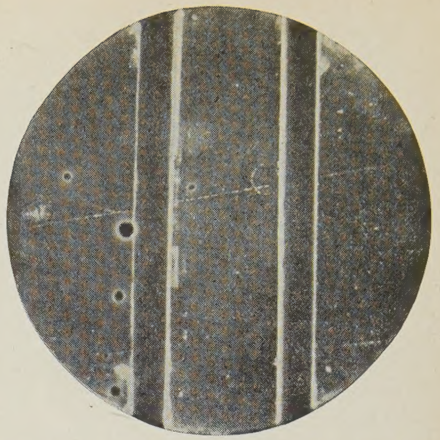


Fig. 11. Track of a corpuscle cleaving its way through a pair of lead plates (Anderson)

circular arcs, and this presumably is due to the strong magnetic field which, although not mentioned in the foregoing discussion, is applied to the gas at right angles to the plane of the picture. An uncharged particle would not describe a curve either in or out of a magnetic field, and moreover (so far as can be judged) would not produce such a chain of closely spaced ions as appears in the pictures. So much, then, is assured.

Trouble begins with the very next question: What is the sign of their charge? If we could tell which of the 2 directions the corpuscle had pursued along the track, we should know whether it was positive or negative; in one case the path would bend to the left, in the other to the right. But, with possible rare exceptions, there is nothing whatever about these paths to indicate the way the particle was going; and we are driven to assume that when a track makes a not-very-great angle with the vertical, the responsible corpuscle was moving downward rather than upward. This probably seems to be a quite unchallengeable assumption, in view of all of the evidence that cosmic rays come from far above the ground. As a matter of fact, it is not indisputable, as will be shown later; but it is probably right in most cases, with an occasional exception. If this assumption be made, it follows from the photographs that some of the particles are positive and some negative, and there is no strong preponderance of either over the other.

It now becomes natural to assume that the negative particles are ordinary electrons, the positive ones protons—that is to say, the smallest, lightest, and most elementary corpuscles of their respective signs, of which we have any knowledge. Assuming this, and knowing the strength of the magnetic field pervading the expansion chamber, the observer may compute the speed and the kinetic energy of any particle of which he can measure the curvature of the path.

Prodigious Energy of Cosmic Ray Corpuscles

The values of kinetic energy which then emerge from the data are fantastically great—tens, scores, nay even hundreds of millions of electron-volts! This unit is not so well known as it should be, and if these values be translated into ergs or calories, they will seem absurdly small; therefore some comparable values will be given to show their proper scale. The highest amounts of energy borne by any particles hitherto known (those of the alpha-particles emitted by certain radioactive elements) are less than 10 million electron-volts. The largest energy which physicists as yet have succeeded in imparting to protons or electrons, in reliable and reproducible experiments, is smaller than 2 millions of these units; even $^1/_4$ of this amount rarely is attained. Energy released in the most vehement chemical changes, such as the formation of hydrogen molecules or water molecules out of their atoms, is seldom as much as *10* electron-volts per molecule involved. The corpuscles which cause the cosmic ray ionization are therefore many times more energetic than any others that are known. Figure 11 shows a piece of confirmatory evidence—the path of a particle that has traversed 2 lead plates several millimeters thick without appreciable loss in speed, for apparently its path is curved no more on one side than on the other! Notice also that this fast-flying corpuscle has hurled a slower one out of each of the plates.

The third of the methods for observing cosmic rays at least must be mentioned; it deserves much more space than can be given here. Say we have a cylindrical tube of metal, with a very slender wire along its axis, and containing air at a suitable pressure; if a suitable voltage be applied between the wire and the tube wall, the passage of such a corpuscle as has been described will provoke an electrical discharge, transient but vigorous—a sort of mild electric spark. The discharge may produce a click or a thud in a loud-speaker, and an observer, sitting by and listening, may count the corpuscles that intersect the tube until he tires or the apparatus fails; or it may make some sort of a mark on a moving film, and the observer in his leisure may total the marks—not so spectacular, in itself, as the expansion chamber with its superb pictorial record!

In some ways this "counter" is inferior, but it enjoys one huge advantage: It is continuously

sensitive; it is, so to speak, vigilant *all* of the time and notices all of the corpuscles that dash across the tube, while the expansion chamber notices only those that pass in a certain brief interval of each of its cycles. Even its most obvious defect, that of not showing the direction of the path, can be remedied partly by setting up 2 or more counters in line, and arranging the circuits so that the apparatus will "speak" only if a corpuscle traverses all of the tubes in a single flight. Johnson has set up no fewer than 37 in a group, each connected to a neon lamp (Fig. 12); now and then several of the lamps will flash at once, betokening the passage of an ionizing particle through all of the row of counters to which they are attached.

In Fig. 10, to revert to the expansion method, appears a remarkable sight: 2 tracks diverging from a single point, located a little outside of the picture, somewhere in the solid wall of the expansion chamber. This is not unusual, nor is it unusual to see a single track starting from some solid object within the field of view. Evidently these ionizing corpuscles do not proceed in every case from the depths of outer space, or the extreme heights of the atmosphere. At first this seems to contradict the earlier inference that the cosmic rays come down from high above; but actually, there is no contradiction. These particles apparently have been released and launched upon their flights by some sudden release of energy, at the place from which they started; and it is legitimate to assume that a bundle of energy, presumably in the form of a photon or corpuscle of high frequency light, did come from far above and was absorbed at the point from which the tracks diverge.

For such a process there is a well-known close analogy. Suppose that the moistened air in an expansion chamber be irradiated with X-rays, which is to say, with streams of corpuscles of high frequency light, though not so high a frequency as would have to be postulated for cosmic rays. No visible track whatever marks out the path of such a corpuscle; but here and there in the chamber (when the expansion takes place) may be seen the tracks of electrons,

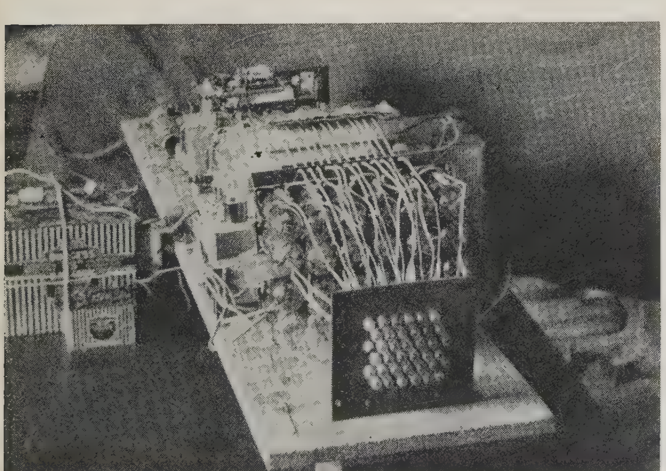


Fig. 12. "Hodoscope" or assemblage of tube counters each attached to a neon lamp (Johnson)

springing out of the walls of the chamber or even suddenly commencing in the body of the gas itself. Each electron has received a part or the whole of the energy of an X-ray photon. The photons ionize the gas not directly, but through these "secondary electrons" as their intermediaries.

Now the photograph that appears in Fig. 10, and many others like it, show that this sort of thing occasionally happens when cosmic ray ionization is being observed. Does it *always* happen? Do all of the ionizing corpuscles, whereof the flights are photographed with expansion chambers, detected by counters, summed up by ionization chambers—do *all* of these corpuscles spring from the lower atmosphere itself or from solid objects in or near the ground, being launched on their courses by photons that come to the earth from the higher air or from the depths of space? Or do some or most of them come from the depths of space themselves?

Competition of Theories Animates Study

It is the competition of these theories that at present animates the study of cosmic rays with lively conflict of opinion which may continue for years.

The former or "photon" theory was first upon the scene. Probably the earliest argument, tacit or explicit, ran as follows: Radioactive bodies emit electrons, positive particles, photons; of all these 3, the last-named are by far the most penetrating, and come nearest to rivalling the unequalled penetrating power of cosmic rays; what more natural than to take them as the proper analog? To put the argument rather more strongly: If we compute the energy that must be owned by (a) a proton (b) an electron, and (c) a photon, to penetrate 200 m of water (remember Regener's experiments!) the value in case (c) turns out surprisingly big, but the values in cases (a) and (b) are appallingly bigger yet! Thus we do not have to postulate quite such outrageously high energy values if the primary particles be assumed to be photons, as in the other cases. But this early argument, not very strong at best, is impaired seriously by the fact that the energies of the charged particles, measured in the way described (by the curvatures of their paths in a magnetic field) are found indeed to be colossally great.

There is some hope of distinguishing between the theories by analyzing the trend of ionization-vs-depth curves—Regener's underwater curve, and that of Fig. 8 in which the "depth" is measured in air from the top of the atmosphere downward, and curves of Millikan's extending over the lower reaches of the atmosphere and downward into water. Thus, if the primary cosmic rays were photons all having the same frequency and therefore the same energy, and were raining down upon the earth from all parts of space equally, these curves would have certain definite shapes. They do not have these predicted shapes, but the discrepancy does not ruin the photon theory, for one may easily postulate that the incoming photons have a variety of energy values. To decide whether the curves are better explained by a suitable distribution of photons of various energies,

or by a suitable distribution of infalling electrons of various energies, is a formidable task.

There is another chance of distinguishing between the theories—the chance that has sent many a physicist on pilgrimage, luring him out of his laboratory and leading him far over the face of the globe. To grasp the contrast as sharply as possible, suppose first that the primary cosmic rays are photons which in the depths of space are dashing about in all directions equally. Those which happen to come toward the earth will not be deflected, not at least until they reach the atmosphere, onto which they will descend as a rain everywhere equally strong.

Suppose next that the primary cosmic rays are electrons or protons, their energy amounting say to a few hundred millions of electron-volts, dashing about in the depths of space in all directions equally. Those which happen to come toward the earth *will* be deflected; for the earth, being a mighty magnet, is surrounded by the invisible aureole of its magnetic field stretching far out on every side into space. Owing to these deflections they will descend to the earth as a rain which falls, not everywhere with equal strength, but most strongly at the magnetic poles and most weakly at the "magnetic equator" which encircles the earth midway between the poles (slanted at about 17° to the well-known equator). The intensity of the cosmic ray ionization then should be a function of "magnetic latitude" (measured from the magnetic equator) with a minimum at that equator and equal maximums in magnetic latitudes near 90 deg north or 90 deg south. The form of the function can be computed from the assumption made about the energies of the electrons or protons; the mathematical groundwork for the theory was laid, years ago, by Störmer for another purpose (he attributed the aurora to charged particles coming from the sun) and has been developed for the present purpose by Swann and Lemaitre and Vallarta. These last-named have found in particular that the intensity of the rays should be constant over a wide zone around each magnetic pole, the diminution being confined to a limited zone around the magnetic equator.

Fig. 13. Ionization chamber set up under a tent at a great altitude (Compton)

Charged Particles or Photons?

Is, then, the ionization due to cosmic rays dependent on magnetic latitude, and in the way forecast by the theory that the primary rays are charged particles raining down onto the earth from space? Or is it the same all over the globe, as the photon theory requires?

This is the question of the hour in cosmic ray research. A great ensemble of expeditions, to places ranging from Spitzbergen in the north to New Zealand in the south, was arranged by Compton in 1932; most of them by now have reported, and it appears from their data that there is indeed a sinking of the intensity of the ionization as the magnetic equator is approached. Clay also found the ionization falling in strength as he cruised from temperate waters into tropical. Those who have toured in high northern latitudes unite in declaring that there is a broad zone of constant intensity; but this is conformable with both of the theories. The critical region is that around the 2 equators, where few observers as yet have gone and humidity makes the measurements precarious. Another great series of expeditions has been arranged by Millikan, and judgment certainly should be reserved until their data are ready.

While awaiting the decision as to the latitude-effect, what can be said with assurance? This much, at least: Cosmic ray ionization is due directly to particles, of which the individual energies are enormously greater than any with which we ever have otherwise found electrons, protons, or photons to be endowed. Some of these particles certainly are charged, some may be uncharged; some, and possibly all, derive their energy from corpuscles of light. At any rate, there are these parcels of colossal energy, owned temporarily by particles of electricity, of matter, or of light. Whence did they come? How did the corpuscles acquire them? There are a couple of relatively unsensational theories: If the primary particles be protons or electrons, it is conceivable that they may have acquired their vast kinetic energies in falling through great distances exposed to mild electric forces in interstellar space, or barely possibly in earthly thunderstorms. If these can be excluded (a triumph of the photon theory, for instance, would eliminate them, though the opposite event would not establish them) the field lies open for the wildest and grandest of speculations. Transmutations hitherto unknown, syntheses of heavy atoms out of hydrogen, melting of atoms into radiation, strange processes that occurred in the infancy of the universe—all of these have been invoked to explain the cosmic rays. Perhaps a physicist may be excused for lapsing from the cool detachment which is proper, and frankly hoping that as our knowledge of the radiation grows, some one among these dazzling theories finally will become inevitable.

Lightning Experience With New Transformer Connection

Distribution transformers in several locations on a New England system have been operating for several months with the primary lightning arrester ground interconnected with the transformer secondary neutral. Experience over the past few months definitely indicates the advantages of this connection in reducing troubles due to lightning, without increasing the hazard to the customers' wiring. Increased clearances on transformer primary bushings also reduce the number of failures.

By
T. H. HAINES
MEMBER A.I.E.E.

C. A. CORNEY
MEMBER A.I.E.E.

Both of the Edison Elec. Illum. Co. of Boston, Mass.

INTERCONNECTION of the primary lightning arrester ground with the transformer secondary neutral was made on 777 distribution transformers located in 7 New England towns during the summer of 1932. The highly satisfactory operating results which were secured with this new type of connection are summarized in the following paragraphs.

At the A.I.E.E. 1932 winter convention held in New York, N. Y., Jan. 25–29, the authors presented a paper "Lightning Protection for Distribution Transformers," which summarized the results of a 5-year study of lightning arrester protection in New England, where the normal ground electrode resistance is much higher than in most other parts of the United States. Experience outlined in this paper showed that the trouble rate of the protected transformers consistently had been materially less than that of those not protected, notwithstanding the seemingly adverse conditions. It also showed that the effectiveness of the arresters is practically independent of the ground resistance when above a value of 100 ohms. Based upon this paper, an article "Experience on a System With High Ground Resistance," was presented in Electrical Engineering for October 1932, p. 720–3, as part of a symposium on "distribution system lightning protection; operating experiences with lightning arresters."

Based upon a talk presented before the Boston, Mass., Section of the American Institute of Electrical Engineers, Dec. 13, 1932. *Not published in pamphlet form.*

At this same 1932 convention, evidence was presented in other papers tending to show that marked improvement in the protective value of lightning arresters could be realized by the simple expedient of connecting the ground lead of the primary arresters to the transformer secondary neutral wire. This proposal seemed to have merit, particularly for application to the system of the Edison Electric Illuminating Company of Boston, Mass., as by this means it was hoped to benefit by obtaining thereby lightning arrester grounds of less than 100 ohms. The desirability of reducing the ground resistance below this value was conclusively shown by past experience. The secondary neutral, having a multiplicity of grounds, would be expected to show lower resistance values than a single stake driven at the base of a transformer pole.

By means of this connection the arrester is bridged around the transformer windings from primary to

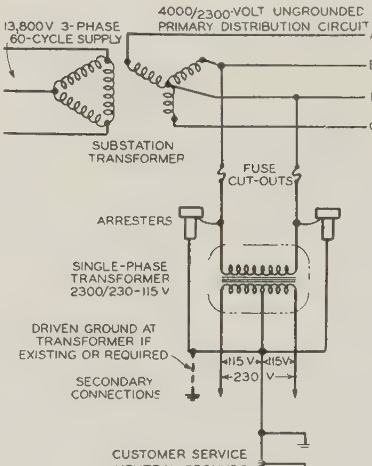


Fig. 1. Diagram of the "shunt" arrester and distribution transformer connection

Conditions under which this "shunt" connection may be used:

1. There must be 3 or more customers with grounded services connected to the secondary; or 2 such customers and a ground rod at the transformer
2. The secondary neutral resistance to ground must not be greater than 200 ohms and a ground rod must be connected at the transformer if the secondary neutral ground resistance is above 25 ohms

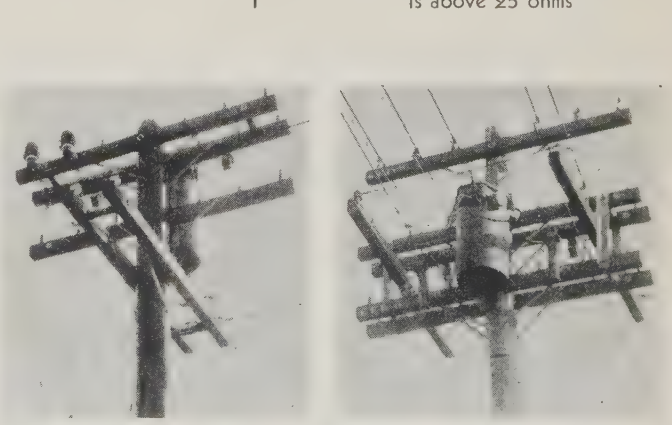
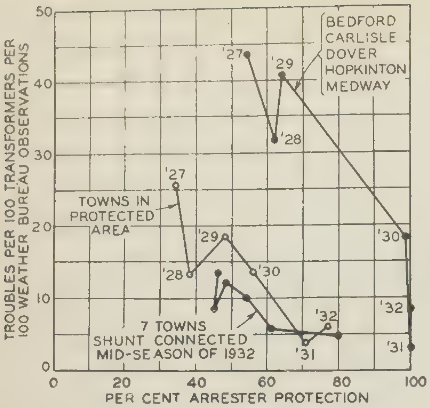


Fig. 2. Single-phase distribution transformer arrangement showing standard connection (left) and "shunt" connection (right)



Values for 1927–30 are somewhat less than those reported in ELECTRICAL ENGINEERING for October 1932, p. 720–3, as a certain number of doubtful cases have been removed from these records in order to compare with the 1932 figures, which had similar cases eliminated

Fig. 3. Variation in trouble rate with percentage of lightning arrester protection 1927–32, corrected for variation in number of lightning observations made by the U.S. Weather Bureau

secondary and effectively protects them. Arresters of the type in use on the system of the Edison Electric Illuminating Company of Boston discharge at about 15 kv whereas normal transformer windings will effectively stand an impulse of 65 kv without breakdown. Several manufacturers are now offering transformers with discharge devices mounted both internally and externally to the transformer and so connected as to utilize the secondary neutral connections as a path to ground.

Early in the spring of 1932 it was decided to make a trial of this so-called "interconnected" or "shunt connection" scheme and 7 towns in the territory were selected. In these towns every single-phase transformer is now protected by an arrester whose ground lead is connected to the secondary neutral except in a few instances where too high a resistance was found on the neutral or too few services were found connected to it. A diagram of the connections used is shown in Fig. 1. No attempt has been made as yet to apply the "shunt" principle to 3-phase transformers. In the course of making the shunt connections, it was found desirable to change methods of construction slightly and install the lightning arrester on the secondary arm. In Fig. 2 are shown the positions of the lightning arresters for both standard and shunt connections.

Results Secured With Shunt Connection

The results which have been secured with the primary arrester ground lead interconnected with the transformer secondary neutral have been highly satisfactory. At the time the first shunt connections were made, it was not expected that transformer troubles would be reduced to the low point which recent records indicate have been secured. In Table I is shown the complete tabulation for 1932 of all transformer troubles due to lightning. The second line of figures in this table are for the 7 towns where the shunt connection was applied.

Progress secured over all the years of the investigation is shown in Fig. 3, the rate of trouble modified by a storm severity factor being plotted against the percentage arrester protection. There are 3 curves in this figure, one showing the change in the number of troubles in 5 towns selected for their past high trouble record as the protection increased, another showing the same record for the entire protected area, and the third for the 7 towns now having the shunt connection. It will be noticed that while the 1932 point for the first 2 curves goes up, the reverse is true for the curve representing the 7 towns with the shunt connection.

The interconnections of arrester grounds with transformer secondary neutrals were made about July 1, 1932. The results for 1932, showing results before and after July 1, are shown in Table II. This table indicates quite conclusively that the interconnections have decreased the rate of troubles due to lightning.

As a matter of fact, out of a total of 777 transformers so protected, there have been just 6 cases of trouble, and these consisted only of fuses blowing. The detailed conditions regarding each of the transformers to which the shunt connection was applied and which gave trouble during 1932 are shown in Table III. It will be seen that in 5 cases arcs across the terminal board were responsible for the fuses blowing, and in the sixth case poor clearance was responsible.

It is significant that with 777 transformers to which the shunt connection has been applied since July 1, 1932, not one has caused trouble with the customers' wiring or with the meters during or after lightning

Table I—Transformer Troubles Due to Lightning in 1932—Troubles Per 100 Transformers

Protected Area Towns Grouped According to % Lightning Arrester Protection	% Protection of Group	Transformers With Lightning Arresters					Transformers Without Lightning Arresters					All Transformers		
		No. Trans.	Fuses Blown	Defects in Windings	Misc. Defects	Total Troubles	No. Trans.	Fuses Blown	Defects in Windings	Misc. Defects	Total Troubles	No. Trans.	Troubles in Year	Total Troubles
100% group, 13 towns	100	1,348	4.2	1.2	2.3	7.6	0					1,348	103	7.6
"Shunt" connected group,* 7 towns	80	978	1.0	0.4	1.2	2.7	252	8.3	0.8	4.0	13.1	1,230	59	4.8
80–100% group, 7 towns	90	1,190	3.3	1.1	2.0	6.4	135	4.4	0.7	6.7	11.9	1,325	92	6.9
60–80% group, 2 towns	77	328	2.4	0.6	2.1	5.2	98	4.1	1.0	2.0	7.1	426	24	5.6
40–60% group, 2 towns	57	345	1.2	0.6	1.2	2.9	264	0.4	0.0	1.1	1.5	609	14	2.3
20–40% group, 2 towns	33	138	0.7	0.7	1.4	2.9	276	3.3	0.7	3.6	7.6	414	25	6.0
Towns over 20%, 33 towns	81	4,327	2.7	0.9	1.8	5.4	1,025	4.0	0.6	3.3	7.9	5,352	317	5.9
0–20% group, 1 town	2	6	33.3	0.0	0.0	33.3	261	1.9	0.4	1.1	3.5	267	11	4.1
Total protected area, 34 towns	77	4,333	2.8	0.9	1.8	5.5	1,286	3.6	0.5	2.9	7.0	5,619	328	5.8

* Per cent protection estimated for mid-season, arresters being added during the summer; this group was 100 per cent protected, 76 per cent "shunt" connected at the end of the lightning season.

Table II—Comparison of Transformer Troubles Before July 1 With Those After July 1, 1932

Protected Area Towns Grouped According to % Lightning Arrester Protection	Total Trans-formers	Troubles Before July 1: Fuses Blown	Defects in Windings	Misc. Defects	Total Troubles	Troubles After July 1: Fuses Blown	Defects in Windings	Misc. Defects	Total Troubles	Troubles After July 1 in % of Troubles Before July 1
100% group, 13 towns	1,348	28	13	15	56	28	3	16	47	84.0
"Shunt" connected group, 7 towns	1,230	22	4	17	43	9	2	5	16	37.2
80–100% group, 7 towns	1,325	25	8	18	51	20	6	15	41	80.5
60–80% group, 2 towns	426	6	1	6	13	6	2	3	11	84.5
40–60% group, 2 towns	609	2	2	5	9	3	0	2	5	55.6
20–40% group, 2 towns	414	5	2	9	16	5	1	3	9	56.3
Towns over 20%, 33 towns	5,352	88	30	70	188	71	14	44	129	68.5
0–20% group, 1 town	267	1	0	0	1	6	1	3	10	1,000
Total protected area, 34 towns	5,619	89	30	70	189	77	15	47	139	73.5

storms. In addition to making a substantial contribution to similar data accumulating elsewhere, this fact should overcome at least some of the hesitancy shown by many operators to the adoption of this form of interconnection on account of the possible added hazard to the customers' wiring.

While it is admitted by the data on the effectiveness of this form of interconnection for so short a period and for so few transformers is not adequate to enable definite conclusions to be drawn, the evidence which has been presented is such that it is planned to add considerably to the number of interconnected locations on this system before the next lightning season.

Bushing Clearances

Although not directly connected to the problem of the interconnection of arrester ground with transformer secondary neutral, another problem which is important from the standpoint of satisfactory lightning arrester protection is the securing of adequate bushing clearances. It is evident from Table III that no protection will operate satisfactorily if the lightning will arc over within the transformer before the lightning arrester has a chance to operate.

For several years it has been the custom of this company to inspect all transformers after fuse blowing in order to determine the actual location of flashovers. As a result, connection boards have been removed and internal clearances have been otherwise improved when the transformers were passed through the repair shop. Certain transformers, especially small sizes of advanced age and high core loss, were found to give the greatest amount of trouble and could not be reconstructed to improve the clearances. The policy therefore has been

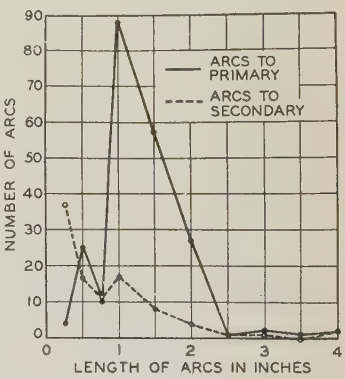


Fig. 4. Analysis of 315 internal arcs in transformers during 1931

Table III—Analysis of the 6 Troubles Which Occurred on "Shunt" Connected Transformers—1932

Trouble Number	1	2	3	4	5*	6
Arrester Data						
Ground rod used	Yes	Yes	Yes	Yes	Yes	No
No. of customer grounds	2	2	3 or more	3 or more	3 or more	3 or more
60-cycle res. of combined grounds (ohms)	0.3	12	24	44	25	5
Transformer Data						
Size (kva)	5	3	10	1.1	10	15
Make	West.	G. E.	G. E.	G. E.	G. E.	West.
Approximate age (yr)	17	27	33	27	16	17
Obsolete	No	Yes	No	Yes	No	No
Case	Iron	Iron	Iron	Iron	Iron	Iron
Terminal board carbonized (above oil type)	Yes	Yes	Yes	Yes	(No board)	No
Internal clearances, primary to case or cover, in	3/4	1/2	1 1/4	?	1	1 1/2
Internal clearances, secondary to case or cover, in	1/4	1/4	1/8	1/2	1/2	1/2
Flashover above oil	Yes	Yes	Yes	Yes	Yes	Yes
Arcs along terminal board	Yes	Yes	Yes	Yes		Yes
Arcs in free space (to case or cover)	No	Yes	Yes	No	Yes	No

Summary:
Overall trouble rate on "shunt" connected transformers in 1932 was 1.15 troubles per 10 transformers per 100 Weather Bureau observations
Overall trouble rate omitting troubles due to obsolete type terminal boards was 0.19 troubles per 100 transformers per 100 Weather Bureau observations
Overall trouble rate of the same towns during the past 5 years (protection with standard connected arresters varying from 45 per cent to 61 per cent during this period) was 13.60 to 5.94** troubles per 100 transformers per 100 Weather Bureau observations.

* A direct stroke to a tree within 100 ft of the transformer was observed.
** Part of the reduced trouble rate on the "shunt" connected transformers is due to removal of inferior transformers from the lines; but it is clear that modern transformers equipped with "shunt" connected arresters would be nearly lightning proof.

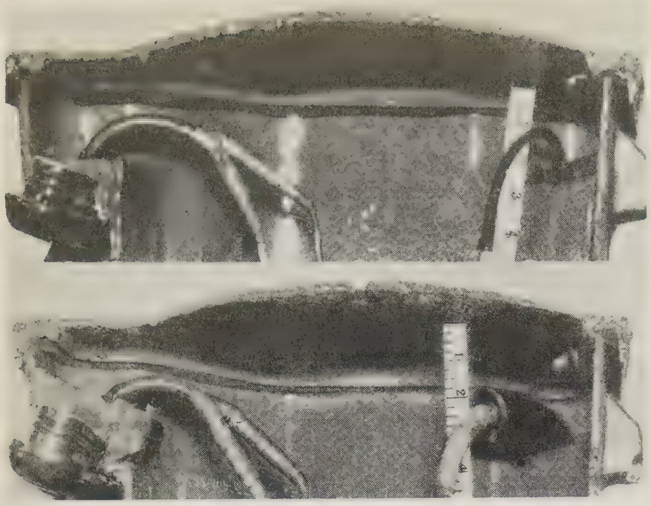


Fig. 5. Old style primary bushing (above) and improved gooseneck bushing (below) on a 5-kva single-phase transformer

Fig. 6. Old style transformer primary bushings (above) and improved gooseneck bushings (below)

adopted of eliminating such transformers from the system.

In 1931 careful measurements were taken of all striking distances where arcing had occurred in and about transformers during lightning storms. These results are shown in Table IV and Fig. 4. It is evident that the number of arcs which have blown transformer fuses occurring where primary clearances are large (over 2 in.) is very small. Accordingly, it has been insisted that the manufacturers supply transformers in the future with a minimum primary clearance of 2 in.

A bushing also has been designed by the Edison Electric Illuminating Company of Boston for use in rehabilitating transformers. This bushing has increased the clearance in those transformers to that demanded of the manufacturer for new transformers. The new and old primary bushings in a transformer are shown in Fig. 5, giving an idea of the improved construction. In addition, this bushing design cuts down the stock items of bushings for repair of transformers from 13 to 2, Fig. 6 showing the new bushings and those they replace.

Table IV—Analysis of Arcs Due to Lightning in Distributing Transformers—1931

Length of Arc—In	Transformers With L. A.'s: To Cover, Core, or Case	Between Phases	Directly Between Prim. and Sec.	Total	Transformers Without L. A.'s: To Cover, Core, or Case	Between Phases	Directly Between Prim. and Sec.	Total	Total Transformers: To Cover, Core, or Case	Between Phases	Directly Between Prim. and Sec.	Total
Arcs to Primary Windings, Terminals, or Leads												
0.125					1			1	1			1
0.25	1			1	2			2	3			3
0.50	9	1		10	14	1		15	23	2		25
0.75	1	2		3	1	5	1	7	2	7	1	10
1.0	22	9	1	32	29	22		51	51	31	1	83
1.25	1	5		6	2	3		5	3	8		11
1.50	12	11	1	24	10	17		27	22	28	1	51
1.75						1		1		1		1
2.0	6	1		7	10	7	2	19	16	8	2	26
2.5							1	1			1	1
3.0	1			1			1	1	1		1	2
3.5	1			1					1			1
4.0			1	1			1	1			2	2
Total	54	29	3	86	69	56	6	131	123	85	9	217
Arcs to Secondary Windings, Terminals, or Leads												
0.25	19	3		22	13	2		15	32	5		37
0.50	12			12	5			5	17			17
0.75	2	1		3	6	1	1	8	8	2	1	11
1.0	6	1	1	8	9			9	15	1	1	17
1.5	2		1	3	4	1		5	6	1	1	8
2.0					2		2	4	2		2	4
2.5							1	1			1	1
3.0							1	1			1	1
4.0			1	1			1	1			1	1
Total	41	5	3	49	39	4	6	49	80	9	9	98

The Oberhasli Hydroelectric Development

IN SWITZERLAND, the country of the "white coal" as electricity is called there, another important electrification has been accomplished by the construction of a large seasonal storage plant, the Oberhasli hydroelectric development above Meiringen in the Bernese Oberland. Construction work on the first step of this project was completed recently and the Handeck generating station was placed in regular operation on October 1, 1932.

The entire development utilizes the precipitations as well as the melting water of a total area of 43 square miles, formed mostly by the glaciers of the famous Bernese Oberland. Since the natural flow of water from this area is such that about 95 per cent of the total annual flow takes place during the 6 summer months, and only 5 per cent during the 6 winter months, it was essential to provide huge storage basins in order to have the water collected during the summer available for the high peak demand during the winter. Natural conditions were favorable so that it was possible to create 2 large artificial lakes, Grimsel Lake (Grimselsee) and Gelmer Lake (Gelmersee) having capacities of 3.5 billion and 450 million cu ft, respectively, corresponding to a total storage capacity of 130 million kwhr. The 2 lakes are connected together by means of a tunnel, thus forming one huge reservoir.

Grimsel Lake has a surface of 27 million sq ft and a total length of approximately 3.5 miles. It is formed by 2 dams, the Seeuferegg dam and the Spitallamm dam. Because of its size, the Spitallamm dam, which at present is said to be the largest in Europe, is the outstanding feature of the entire development. Dimensions of this dam are as follows:

Height above bottom of foundation	375 ft
Radius	295 ft
Length	850 ft
Amount of concrete	12,000,000 cu ft

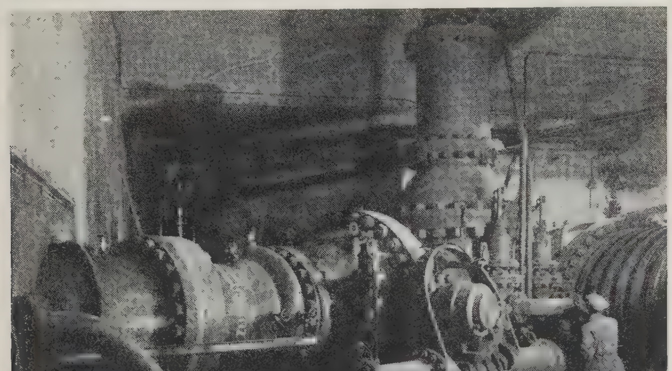
Only those familiar with the climatic conditions 6,300 ft above sea level can appreciate the difficulties of construction. Because of the extreme severity of the winter, work could progress only during a few months per year; but despite this handicap the dam was completed several months ahead of schedule.

Water accumulated in Grimsel Lake is conducted through the previously mentioned horizontal tunnel to Gelmer Lake and from there by means of a pressure line to the Handeck generating station. This pressure line consists of steel tubes having a diameter of approximately 8 ft; it is installed in a tunnel 3,700 ft long, and spans a difference in altitude of 1,750 ft at a maximum inclination of 72 per cent.

Handeck station is equipped with 4 vertical generating units, each composed of a 30,000-hp Pelton turbine and a 28,000-kva generator operating at a speed of 500 rpm and delivering power at 11 kv;

Prepared especially for ELECTRICAL ENGINEERING from information contributed by F. Dossenbach, Director, Official Information Bureau of Switzerland, New York, N. Y. *Not published in pamphlet form.*

View of Grimsel Lake showing Seeuferegg dam at the left and Spitallamm dam near the center



Pressure line feeding the 4 30,000-hp Pelton waterwheels at Handeck station. The line is 8 ft in diameter; the head, 1,750 ft

Handeck generating station where the water stored in Grimsel Lake is utilized

this is stepped up to 50 kv by means of 4 28,000-kva transformers.

The problem of transmitting power from the Handeck station to the load center presented serious difficulties. Because of the many avalanches in the neighborhood of the station regularly every winter, for reliable transmission it was considered necessary to use underground cables. These 50-kv cables are installed in a special tunnel 3.1 miles long connecting the station with the village of Guttannen. The tunnel has been built sufficiently large to accommodate a small electric car which during the winter season forms the only means of communication between the station and the villages in the lower part of the valley. From Guttannen power is transmitted over 4 50-kv overhead lines to the Innertkirchen transformer station where it is stepped up to 150 kv by means of 4 water cooled outdoor transformers; from there it is carried over 2 150-kv lines to consumers in the central part of Switzerland.

As a future extension to this development it is planned to collect the water at the turbine outlets of the Handeck station and to conduct it by means of tunnels and pipe lines to another generating station which will be built on a site near the present Innertkirchen transformer station. Thereby it will be possible to increase the annual production of the development from the present value of 230 million kwhr to approximately 540 million kwhr.

Private Versus Public Enterprise

AN ADDRESS "The Era of Public Enterprise" was delivered by Walter Rautenstrauch, professor of industrial engineering, Columbia University, New York, N. Y., at a meeting of the Advertising Club of New York, held March 1, 1933, in that city. Following Professor Rautenstrauch's address, which extolled the benefits expected from increased public enterprise, an address was given by Dr. Virgil Jordan, president, National Industrial Conference Board, Inc., New York, N. Y., in which the case for private enterprise was argued. Excerpts from these 2 addresses follow. These conflicting views are published without editorial comment, in the hope that, between them, the readers of ELECTRICAL ENGINEERING may find constructive suggestions and be stimulated to further ideas. Comments, criticisms, and suggestions are invited, as "letters to the editor"; they will be considered for possible publication.

I—Public Enterprise

By
WALTER RAUTENSTRAUCH Columbia Univ., New York, N. Y.

THE MANY suggestions for the solution of our economic difficulties put forward during the past 3 years of the depression are so varied in their proposals and in the principles underlying them that it seems almost hopeless for us to arrive at any concerted action to get us out of our difficulties. This seems to be due to 2 causes: First, an entire lack of common understanding of basic economic principles; and second, a lack of vision on the part of many people to see beyond the horizon of their limited and confining experiences.

Business enterprise has been too long regarded from the narrow point of view of special interest. We fail to realize the fact that it is impossible for any unit in our economic structure to stand by itself without the strong support of all the other units which together make up the complete structure of our economic society. In the same manner that the whole physical body is endangered when one of its organs fails to function properly, so also the whole body of society is endangered when the functioning of one or several important elements upon which it depends become deranged. The violation of fundamental economic principles on the part of those who are responsible for the creation and maintenance of our credit-capital institutions not only affects the well-being of these institutions themselves but also affects, most seriously, all other institutions in society depending upon the correct functioning of our credit-capital agencies.

Our manufacturing institutions operating as if there were no limit to our natural resources and no limit to the consumer market, build up productive capacity out of proportion to the purchasing power of wages to consume their products. Agriculture with its tremendous burden of debt largely self-imposed in the era of speculation finds that its costs of production are in excess of affective consumer demand. As we examine the social mechanism we find the disastrous results of individualistic enter-

Based upon addresses presented by Professor Rautenstrauch and Doctor Jordan, at a meeting of the Advertising Club of New York, N. Y., March 1, 1933. *Not published in pamphlet form.*

prise operating without a full knowledge of the basic principles upon which its own successful operation is founded and without any regard for the economic well-being of associated and dependent enterprise. The social wastes of rugged individualism, and frankly, the selfish and non-cooperative operation of private institutions is in a large measure responsible for our present condition.

It must be apparent to any observer of social phenomena that we cannot continue in the future if present practices of private enterprise continue. We are passing through a period of social change and we must adjust the operations of our institutions to conform to these changes. We must embark on the project of public enterprise, that is, enterprise operated in the public interest, if we are to establish and maintain a well-balanced and healthy social order. If we were to build up a balanced and orderly system by which we could provide ourselves with the material things of life we must first adopt a wholly different point of view than has obtained in the past with respect to business enterprise.

The changes brought about in our methods of manufacture by means of which we convert the natural resources into commodities and services have altered the relative claims of capital and labor to share in the goods produced. Many economists point out the fact that there has been no significant change in the percentages of the total population which was gainfully employed. In 1870 the percentage was 44.3, in 1910 it was 53.3, and in 1930 it was 49.5. It must be remembered that while the total percentage of those gainfully employed has not changed materially in the past 2 generations, the shift in the nature of this employment is quite significant. In 1870 approximately 53 per cent of those gainfully employed were in agriculture, 22 per cent in manufacturing and mechanical arts, 1.5 per cent in mining. These so-called productive industries accounted for 76.5 per cent of those gainfully employed; 23.5 per cent were thus employed in services such as professional service, trade and transportation, clerical and otherwise in 1870. In 1930 only 21.5 per cent of those gainfully employed were in agriculture; 28.5 per cent in manufacturing and mechanical arts; and 2 per cent in mining; thus a total of 52 per cent were engaged in that year in the productive industries and the remainder were engaged in services of various sorts.

During this period of 60 years we experienced a tremendous expansion in production due to the introduction of tool power and the substitution of generated energy for human energy. Recent studies show that some of our basic industries have passed the inflection point of their growth and are now tending to level off in growth and become parallel with the growth in population. This is a significant change because the decreasing growth will not permit the reabsorption in industry of those displaced by the advancing efficiency of mechanical operation and, the wages of those remaining will tend to become less in proportion to the number that must make their living in the professional and clerical services and in trade.

Another significant factor is the mounting tide of debt in relation to purchasing power created through wages particularly as it has developed in the past several years. From 1926 to 1930 interest and dividend payments in the United States doubled in amount while wage payments to factory workers dropped 30 per cent. Since 1930 while interest and dividend payments have declined, that decline has not been as great as the fall in factory wage payments which is now down to about 35 per cent of what it was in 1926.

The disastrous situation with respect to our foreign trade is another factor of great concern. The tremendous burden of international debt, the mounting tariff walls restricting the free flow of trade, have their effect on the well-being of every home and fireside in the nation. This whole mass of difficulties has been built up as a result of operating as though there were never any economic principles formulated and made available for use. Individuals in their private affairs have burdened themselves with debt through the use of installment buying plans and through speculation and have incurred obligations for future payments of debt with utter disregard of basic and fundamental principles of economy.

Each unit of the industrial system, private, corporate, and even public, operating on the basis of immediate profit, is not responsive to human need. An aggregate of practices without regard to the effects of one group of practices on another group nor on the economic system as a whole has been demonstrated to be unworkable and cannot include that most fundamental of all conditioning factors—the economic well-being of the forgotten man.

Two important principles of operation of our whole economic system may be emphasized:

1. The first principle is that credit-capital must be apportioned properly between that which is founded upon capital goods (plant machinery and producing equipment) and that which is available for working capital and the movement of consumers' goods. The flow of capital into these 2 channels must be regulated and controlled by cooperative actions such as does not obtain under our system of private enterprise.

2. The second principle is that the relative claims of labor and capital to the goods produced must be adjusted to workable proportions. Accordingly we must find what these workable proportions are and adjust our commercial and economic practices in conformity thereto. The maintenance of these balances can be obtained only by cooperative action and such action demands the institution of public enterprise; that is, enterprise founded upon cooperative action for the public good.

Following are a few methods of control which seem to be desirable:

1. Both national and state banks should be under more rigid regulation in their participation in security flotations in order that they may take their legitimate place in trade with more active participation in commercial loans and less dependence on collateral and brokers loans.

2. All offers to the public for investment should be accompanied by full and complete information on the economic characteristics of the particular enterprise and the industry as a whole of which it is a part.

3. Materially reduce all interest rates on municipal, state, and federal bonds.

4. Capital should be at the risk of the business with respect of earnings just as labor is at the risk of the business with respect of employment and wages. To this end fixed interest investments should be converted to the common stock type with interest and dividends payable only when earned.

5. All balance sheets and operating statements of public interest should be on a revised and standardized form permitting of accurate

and complete interpretation of the earnings characteristics of the enterprise and the position of the business with respect thereto.

That there are well-defined and determinable laws of growth, applicable to industries as a whole, and to particular businesses, is a fact which is not generally recognized and which is most important in any consideration of social growth. It is the same law which applies to the growth of population in any continental area, and by means of which it is possible to predict within reasonable degrees of accuracy what the population of a given country probably will be in the immediate future years.

The department of industrial engineering of Columbia University is engaged in a study of the laws of growth of our basic industries and the results obtained so far are exceedingly interesting and instructive. From personal observations of the data assembled to date, it is found that some of our basic industries have begun to level off in growth, that is, to increase at lesser rates than obtained in the earlier part of the present century. But it is not at all unlikely that we may experience a second period of growth and expansion if we alter our present economic practices, particularly those under which the relative claims of labor and capital in both manufacture and agriculture are adjusted to more workable proportions. . . .

II—Private Enterprise

By
VIRGIL JORDAN President, National Industrial Conference Board, Inc., New York

THE REAL difficulty with the pattern of public enterprise, the idea of having a government of any sort, whether of engineers, economists, or Tammany politicians, run our industries and businesses in an orderly fashion lies in this simple fact: We, as a people, and as individuals, are not made in the way we would have to be to fit into the pattern. Perhaps we can be made to fit some day, but that is a question of eugenics, not of economics or engineering. . . .

In fact the phrase "public enterprise" is a contradiction in terms. There never has been in this country any public enterprise that amounted to anything in comparison with what individuals have done for themselves. The public, which is merely a fuzzy word for the great mass of individuals who live in this part of the world, is quite incapable of any enterprise or creative action. Certainly the government, which consists of a number of salaried employees of the public, is wholly unable to create anything without the aid of individual enterprise and spends most of its energy interfering with or regulating the activities of individuals and taking part of the results of their enterprise away from them. I do not object to this; it is necessary, wherever large numbers of people live and work in the same place and at the same things, to prevent them from stepping on each other; but to call this purely negative policing and taxing function creative or to imagine that you can get anything you can properly call enterprise out of public officials is a delusion. . . .

This is not said in criticism of public officials. As individuals they are like every one else. Their impotence lies in the basic fact that in the present stage of human development creative action is possible only by individuals or, at best and in very rare cases, by small groups of individuals bound together by a common purpose. Almost everything of any lasting importance that has been done in the world has been done by somebody and not by everybody, and the process of creation is likely to continue on that basis for a long time to come. The fact that the same is true of almost everything bad that has been done only emphasizes the supreme importance of the individual as a creative agent and also as the end and purpose of all creative activity. Although the whole world is on committees, so far as is known, nothing has ever been done by them. . . .

Of all the stupidities of this strange period of distorted perspective there is none more inexcusable than the prevalent skepticism regarding the social value of individual enterprise in industry and trade. If we were in our senses we might well ask ourselves what sort of civilization we would have today, and what kind of standard of living we could support, if through the past century men had not been willing to stake something on inventions, improvements, and new procedures which have enabled us to produce and distribute goods and services more cheaply and abundantly, and how these things could have been accomplished without the spur of individual desire for prestige, power, and profit. Even though the natural energy and material resources of this continent are the greatest in the world, it is questionable whether we could have accomplished anything with them without the energies of human ambition and the forces of human desire that lie at the basis of all economic effort. To industry in this fundamental sense we owe everything that we have and are, and there has never been and will never be a substitute for it, whether from the laboratory of the scientist, the study of the economist, or the halls of the legislator.

Engineers and economists have unquestionably an important part to play in the reconstruction of prosperity and the restoration of stability in American business, but in the wave of skepticism about the part which business enterprise has played in our past progress there is grave danger that the engineer and economist may claim too much for themselves and bring themselves into contempt. Did not Veblen himself, the earliest apostle of the dictatorship of the expertariat, call the engineers "a somewhat fantastic brotherhood of over-specialized cranks, not to be trusted out of sight except under the restraining hand of safe and sane business men?" Economic and social advancement have always depended and will always depend fundamentally upon the forces of human ambition and the instincts of

individual initiative. These the engineer and the the economist are all too prone to ignore. They under-estimate the driving force of human desire and they are rarely, if ever, concerned with the human impulses and purposes of all economic activity. In so far as they fail to take these actualities into account, their calculations will prove useless and their schemes for social reconstruction will lack all practical importance. It is absurd to try to reduce the record of human progress to terms of mechanical energy and express all human accomplishment in horsepower. There is no source of wealth and no means of producing it except the energy and intelligence of men. All our natural resources of power and materials are meaningless and worthless without the human mind and spirit that make something of them, and men will always be something more than what they eat. Certainly prosperity is not a tune that can be ground out of our economic machine by putting a set of blue-prints into it like a roll in a player-piano and pushing the proper buttons.

The American people above all others, by tradition, breeding, and experience, are stamped with the pattern of individual enterprise. In fact we are practically incapable of any sort of group effort to any creative end, and have to be mobilized for concerted action even in emergencies by extreme measures. The industries of this country—the greatest industrial nation in the world—have never so far formed or supported any comprehensive, strong national organization even in order to advance their own interests, and certainly none for any nationally constructive purpose. Though they need it today more than ever and their very existence may depend upon it, it has so far been impossible for even the leading industrial executives of this country to develop any constructive plans to deal with the economic situation and act together to put them into effect. . . . In fact the net result—the only revolution that is taking place is one in the direction of greater individualism, a drift back to the land, a decay of big business, a revival of small enterprise, a process of decentralization and digging in for self-sufficiency and increased independence all along the line. So far from putting a premium on the idea of public enterprise and centralized control, this depression has only made the average American more fed up than ever with the futility of government and emphasized the tendency to decentralization and dispersion of enterprise already under way before the depression came. . . .

Of course there will always be great need and great opportunity for public spirited enterprise, which is a quite different thing from public enterprise. In fact a great deal of our so-called public enterprise today is distinguished by the absence of public spiritedness. There will also be unlimited room for the slow building of cooperative action among groups of individuals based on a deeper and broader understanding of the basic conditions of national prosperity. But it is a mistake to believe that the constructive results of such slow development can be achieved at a single stroke merely by putting the responsibility for enterprise in the hands of public officials.

In some aspects of our economic life like the production of electric energy and the manufacture of money and credit—both basic public utilities upon which every one depends—increasing public control may be coming, but in all other respects I believe that we are facing the greatest era of private enterprise and most vigorous revival of individual effort ever seen. . . . The use of independent power plants is growing, and our experience during this depression will probably force us back to a currency basis, at least until we get a better organized banking system. In the hoarding of currency in this depression rugged individualism reached its extreme expression and logical conclusion. But whether this extension of control over the utilities and banking happens or not, does not much matter because the depression will accentuate the basic tendency in the rest of our economic life toward diffusion, decentralization, and individualization of enterprise. It has not in any way retarded the advance of science, the development of new processes and products, all of which are individual efforts and can never be stopped, planned, or controlled because they are born in the minds of individual men. It has driven men into every sort of occupation and trade for the sake of security and independence, and led to launching of thousands of new concerns free of debt or burdensome overhead. These are already winning the market away from the older, bigger concerns handicapped by unwieldy capital structures, elaborate organization, inflexible methods and ideas. These new upstarts may become the giants of some later time, but in the meanwhile they will be the chief basis of business revival because they are better adjusted to the conditions and requirements of today. So far from bringing a greater part of our business enterprise into the position of public control, the depression has dispersed the bulk of it into forms and in channels that are less susceptible than ever before to such control. The growth of superpower systems may lead to public control of them, but the important fact is that they have made possible the wider distribution and decentralization of production for local rather than national markets, and the public control of business is becoming less possible and less necessary. I look for less and less dependence of business on nation-wide markets for the bulk of consumer products, and likewise relatively diminishing importance of long distance haulage for railroads and of international trade. We are going to become not only a more self-contained nation but a nation of more self-contained regions, and more independent individuals.

All these things and much more . . . are implied in the new era of individual private enterprise that is to open after this depression has passed. If the depression has meant any important change, that change is a reversal of the tendencies toward centralization of control of our economic destinies which may have reached their peak in 1929. But I prefer to believe that the depression has been only a temporary interruption in the steady expansion of prosperity which has sprung from the individual energies of the American people, and that the result will be greater stability and security and larger prosperity than we have so far seen.

Sheath Grounds Affect Traveling Waves in Cables

Traveling waves may appear in power cables connected to high voltage transmission lines. The differences in voltage that will appear between the conductor and sheath of a cable at various points depend upon the nature and location of the cable sheath grounds. A few of the results of a considerable number of tests made to determine their effect are presented in this article, and some conclusions regarding protective measures are drawn.

By
E. BECK

Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

POWER CABLES directly connected to high voltage transmission lines have been subjected to numerous studies to determine the effect of traveling waves and the magnitude of the voltages which result from the reflections and refractions of these waves at the ends of the cable. There appears to be fairly close agreement as to the protective value of cables themselves; in general, low voltage cables connected to highly insulated lines such as those on wood poles are not likely to be self-protective. High voltage cables connected to steel tower lines will often be safe and not require protection.

There is a phase of the behavior of traveling waves in cables which apparently has received little attention. The usual treatments of surges in cables consider the cable sheath grounded throughout its length. For this assumption the simple relations usually given are quite correct. It is not necessarily a fact, however, that in practice the cable sheath is grounded throughout its length. Often there may be a considerable ungrounded length of sheath between the entrance and the first sheath ground. It may even be the case that the sheath is entirely ungrounded or grounded through high resistance. The cable potentials in such cases are of practical importance. Some theoretical considerations led to the suspicion that a cable whose sheath is not grounded at the entrance may be subjected to high voltages internally. A series of tests on cables was made and has shed some light on the subject. The cable set-up used is shown in Fig. 1.

To lead up to the situation let us first consider a cable whose sheath is completely isolated from ground. Theoretically, such a cable should act very much like an open line with the same order of surge impedance and velocity of propagation, since the presence of the ungrounded sheath has little effect on the distributed constants. It was found to be so by test. The measured surge impedance of the cable with ungrounded sheath was 492 ohms, and the velocity of propagation 890 ft per μsec.

There should be no appreciable voltage across the cable insulation because the sheath will pick up by induction a voltage of the same order as the con-

Full text of a discussion of a paper "Traveling Wave Voltages in Cables" by H. G. Brinton, F. H. Buller, and W. J. Rudge, Jr., presented at the Middle Eastern District meeting, Baltimore, Md., Oct. 10–13, 1932.

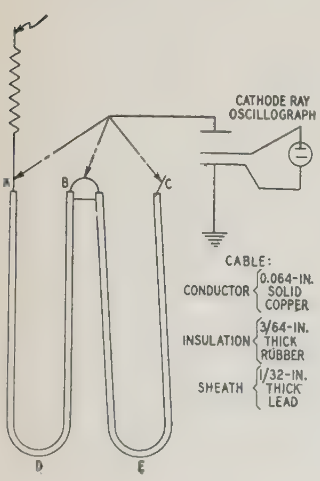
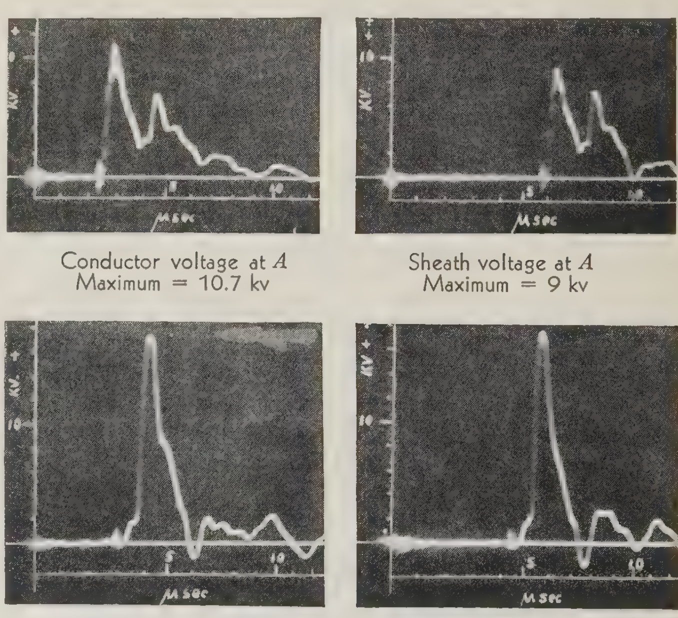


Fig. 1. Diagram of connections for cable tests

AB = 352 ft; BC = 383 ft; AD = 233 ft; BE = 165 ft



Conductor voltage at *A* Maximum = 10.7 kv

Sheath voltage at *A* Maximum = 9 kv

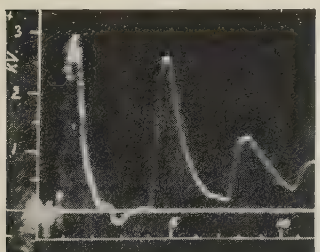
Conductor voltage at *C* Maximum = 17 kv

Sheath voltage at *C* Maximum = 17.3 kv

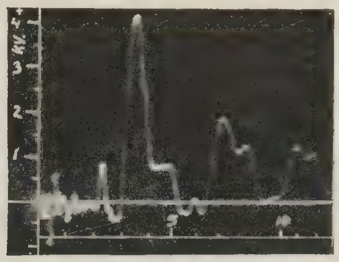
Fig. 2. Voltages with cable sheath insulated from ground

ductor voltage. The tests, illustrated by the oscillograms reproduced in Fig. 2, indicate that this is so. At the far end of the cable the characteristic increase in voltage caused by reflection appears. There is still negligible potential difference between conductor and sheath. Such a cable needs no protection for itself, although apparatus connected to it does.

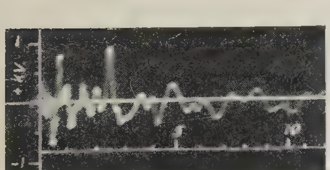
Now consider the sheath grounded at the entrance only. As shown in Fig. 3, the characteristic reduction in conductor voltage takes place, the maximum voltage now being 2.7 kv instead of 10.7 kv. The surge impedance of the cable is now much less, measurements indicated 39 ohms. The velocity of propagation is also less, 450 ft per μsec. The cable now acts in the usually expected manner. The conductor potential appears between conductor and sheath. At the far end, *C*, the usual reflections occur; the sheath potential however, remains zero except for extraneous disturbances. Thus such a cable acts like the cables with grounded sheaths usually discussed. Measurements at *B*, the mid-point, indicate similar effects. A cable grounded at



Conductor voltage at *A*
Maximum = 2.7 kv



Conductor voltage at *C*
Maximum = 4.2 kv

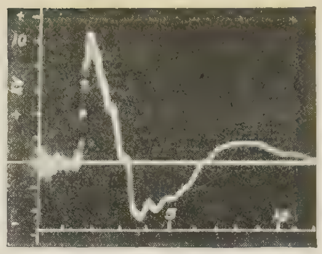


Sheath voltage at *C*

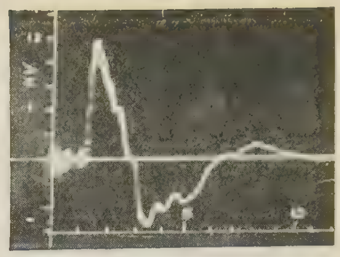
Fig. 3. Voltages with cable sheath grounded at entrance, point *A*

the entrance acts very like one grounded throughout its length and its insulation will be subjected to potential.

Now let us consider the cable with its sheath grounded only at the far end *C*. Oscillograms taken under this condition are represented in Fig. 4. While the surge is traveling from *A* to *C*, the cable acts as if the sheath were insulated, because the surge cannot tell that there is a ground at *C* until it reaches *C*. There is no reduction in entering voltage, therefore, until the reflections and refractions produced at *C* by the grounded sheath return to *A*. The sheath potential at *A* again is of the same order as the conductor voltage, so again there is little voltage across the cable insulation at *A*. At *C* the sheath potential is zero because it is grounded. The voltage on the conductor at this point is reduced below the incoming voltage measured at *A* because the cable turns from an ungrounded to a grounded one; in other words, the change from open line to cable really

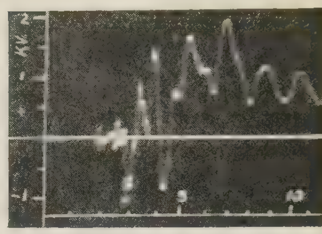


Conductor voltage at *A*
Maximum = 10.5 kv



Sheath voltage at *A*
Maximum = 9.5 kv

Fig. 4. Voltages with cable sheath grounded at far end, point *C*, only



Conductor voltage at *C*

takes place at *C*. Potential develops between the conductor and sheath at *C*. An arrester between conductor and sheath at *A* would do no good because it would not discharge since there is negligible potential difference between the conductor and sheath at *A*. This is important because it may easily appear offhand that an arrester between conductor and sheath would protect the cable regardless of grounding conditions. In the protection of distribution transformers, for instance, it is a fact that if the transformer insulation is shunted by arresters, it is protected regardless of grounds. This does not hold for cables. The point of greatest stress in the cable is at the sheath ground, or at the far end if the conductor terminates there.

Tests with the cable sheath grounded at *B*, the mid-point, gave results at the entrance *A* similar to those obtained with the ground at *C*. Potential across the cable insulation occurred at the mid-point, where the ground was located. At the far end *C* some potential also developed by reflection phenomena. Arresters between the conductor and sheath at *A* had no effect. Arresters at *C* changed the measured voltages.

Conclusions

Many oscillograms were made during these tests under various conditions of grounding and protection. The principal conclusions are:

1. A cable with ungrounded sheath acts the same as an overhead line. Negligible potential will develop between the conductor and the cable sheath and such a cable requires no protection for itself. The traveling wave voltages in such a cable will act as though the cable were an overhead line. Thus short pieces of cable interposed in overhead lines, if the sheath is insulated will require no protection. If, however, the sheath should be grounded purposely or accidentally, the cable will require protection because high potentials will then develop between the conductor and the sheath.

2. The connection of a lightning arrester between the conductor and the sheath at the cable entrance with no ground is not to be recommended in general. If the cable sheath is not grounded for some distance from the entrance, potential differences between the conductor and sheath may not develop at the entrance and the maximum potential difference will probably develop where the sheath is grounded. The arrester between conductor and cable sheath at the entrance may not discharge and therefore will not exert any protective effect on the cable. It will be best to have a definite ground at the cable entrance.

Conductor Vibration From Wind and Sleet

Conductors on electric power transmission lines have been observed to vibrate with amplitudes as great as 20 ft during sleet storms with the temperature just below freezing, and with a heavy wind blowing transversly across the line. An explanation of this phenomenon is given.

By
J. P. DEN HARTOG*
Harvard University, Cambridge, Mass.

VIBRATION in transmission lines due to the action of a transverse wind has been discussed frequently in technical literature of the last few years. Phenomena most commonly observed are those occurring at moderate wind velocities (about 5 mph) characterized by rather high frequencies (5 to 15 cycles per second) and small amplitudes (up to a few cable diameters). This type of vibration is caused by the Kármán vortexes forming behind the wire and is well understood.

Another type of disturbance has been observed, which seems to occur with sharp winds of above 20 mph, with great amplitudes (20 feet) low frequencies (one cycle per second or slower) and mostly associated with sleet formation on the conductors. This phenomenon has been described in detail in a paper by Davison (see "Dancing Conductors" A.I.E.E. TRANS., v. 49, 1930, p. 1444–9) who rightly believed it to be caused by the change in shape of the conductor due to the ice coating and by the consequent change in aerodynamic lift. Davison measured the lift of some specimens in the wind tunnel and found that the lift under certain conditions can exceed even the weight of the cable. However, the mere fact that the wind causes a lift on the unsymmetrical conductor does not yet cause it to vibrate, so that Davison's discussion of the phenomenon is incomplete.

It is the object of this article to give an explanation of the effect and to show how the stability of a transmission line, in this respect can be calculated from the results of an aerodynamic test, whereby both the lift and the drag are determined for various angles of attack.

Consider an element of the cable of unit length subjected to a lateral wind of constant velocity V and vibrating up and down according to the relation $x = a \sin \omega t$ which is the general equation for harmonic oscillation. On account of its vibrating motion the cable experiences a vertical wind component in addition to V.

For example, at the instant that the cable is moving upward with the velocity v the "relative wind" striking it appears to come from above under an angle $\Delta\alpha = \tan^{-1}(v/V)$ as shown in Fig. 1. Since during the vibration the velocity v varies all the

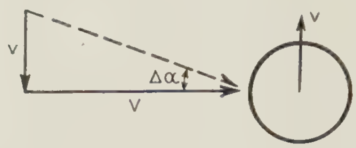


Fig. 1. Force diagram for a lateral wind of constant velocity blowing against a vibrating cable of circular cross-section

time it may be seen that the cable is subjected to a wind of which the direction also varies with the time. For a circular cross-section the force exerted on the cable by the wind will be always exactly in the direction of the wind, or, in aerodynamical parlance, there is only drag, and no lift. Should the cross-section become non-circular due to sleet, this ceases to be true and lift as well as drag appears.

Plotting the drag (wind force in the direction of the wind) as well as the lift (wind force perpendicular to wind direction) against the angle of attack for an elliptical cross-section, Fig. 2 is obtained. The drag is minimum for $\alpha = 0°$, and maximum for $\alpha = 90°$. Due to symmetry the lift must be zero at $\alpha = 0°$ and $\alpha = 90°$ and reaches maximum in between. It is an experimental fact that this maximum is closer to $0°$ than to $90°$. For values of α between $90°$ and $180°$ there is negative lift or downpush.

Now consider a cable element having an elliptical section in the position of $\alpha = 0°$ in Fig. 2 and let it vibrate vertically. While it is moving upward the relative wind strikes it obliquely from above (Fig. 1) and the angle $\Delta\alpha$ is negative (Fig. 2). In other words, while the cable is moving upward it experiences an aerodynamic downpush. In the same manner it can be seen that during downward motion there is lift, so that always the force is directed against the motion. Whenever such a vibration starts the wind will damp it out.

Conditions are quite different, however, when the cable has the position $\alpha = 90°$ in Fig. 2. Incidentally, such a cable has some resemblance to a line with icicles hanging down vertically from it. While the cable is moving upward angle α is $85°$, say, instead of $90°$ and there is *lift;* similarly, during downward motion, angle α is $95°$ and there is *a downward push.* These forces are in the direction of the vibration and therefore put energy into the motion. The cable is unstable; any vibration, however small, will be increased in amplitude by the wind.

This instability is due to the negative slope of the lift curve; a cable in such a position that $\alpha = 60°$ in Fig. 2 would be unstable also. There would be only a constant lift superposed on the variable lift due to vibration. This constant lift would re-

Full text of "Transmission Line Vibration Due to Sleet" (No. 32-91) presented at the A.I.E.E. summer convention, Cleveland, Ohio, June 20–24, 1932; subsequently revised to include new material.
* Formerly of the Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

lieve the towers of some of the load, but would have no other effect.

So far the drag force has not been considered. In Fig. 3 are represented the forces acting on a cable element in its upward stroke while vibrating in the position where $\alpha = 90°$. It is seen that not the entire lift force is pushing the cable up, but only its vertical component; also that the drag force has a *downward* component. Therefore instability occurs when the effect of the negative slope of the lift curve is greater than the damping action due to the drag.

Quantitative Theory for Small Vibrations

Assume that for the cross-section under investigation a lift and drag diagram like Fig. 2 has been determined experimentally by a wind tunnel test. The diagram holds for a particular wind velocity V_0. The lift and drag forces for other wind velocities

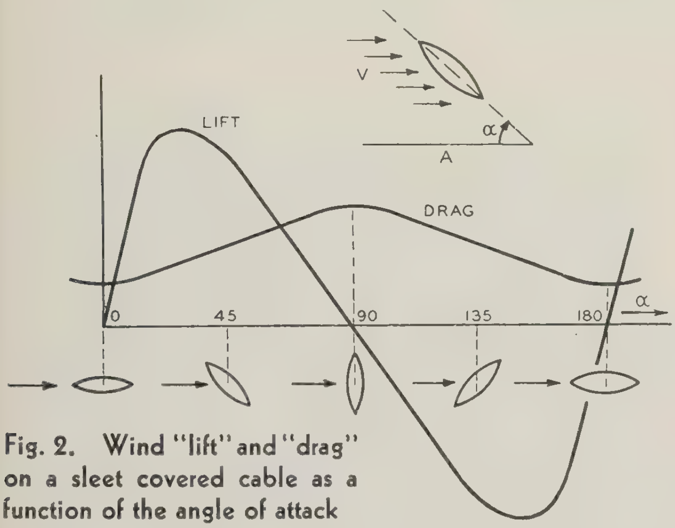


Fig. 2. Wind "lift" and "drag" on a sleet covered cable as a function of the angle of attack

can be calculated by observing that they are proportional to the square of V. (It is understood that this is only approximately so; for airfoil sections in aeronautics the approximation is very good, but for irregular sections as discussed here the error may be considerable.) Therefore the lift L can be computed by the formula

$$L = (V^2/V_0^2)L_0 \tag{1}$$

where L_0 is the ordinate of Fig. 2. A corresponding relation is true for the drag.

Let the cable element execute small vibrations $a \sin \omega t$. The vertical velocity v then is $a\ \omega \cos \omega t$ and the variation in the angle of attack (Fig. 1) is:

$$\Delta\alpha = (a\ \omega/V) \cos \omega t$$

For small values of $\Delta\alpha$ the lift curve is a straight line and the drag can be considered constant. Then

$$L = \frac{dL}{d\alpha} \cdot \Delta\alpha$$

where $dL/d\alpha$ is the negative slope of the lift curve. Let D be the drag at the point considered; then according to Fig. 3 the vertical component of the drag is $D \cdot \Delta\alpha$. Consequently the driving force is:

$$\left(\frac{dL}{d\alpha} - D\right) \Delta\alpha = \frac{a\ \omega}{V} \left(\frac{dL}{d\alpha} - D\right) \cos \omega t$$

In this expression L and D are still functions of the wind velocity; with eq 1 the driving force becomes:

$$\frac{a\ \omega V}{V_0^2} \left(\frac{dL_0}{d\alpha} - D_0\right) \cos \omega t \tag{2}$$

This driving force is of the nature of a negative "viscous" damping. Sustained vibrations occur when

$$\frac{dL_0}{d\alpha} > D_0 \tag{3}$$

The expression $dL_0/d\alpha$ is the vertical distance between the two points of the tangent to the L_0-curve whose horizontal distance apart is 1 radian or 57°. When this distance in Fig. 2 is greater than the ordinate of D_0 at that point the cable is dynamically unstable. The formula shows also that the effect whether it be input or damping, is proportional to the velocity of the wind.

In order to get a quantitative idea of the magnitude of the effect it is necessary to possess experimental lift-drag-α diagrams, like Fig. 2, for the various ice-coated shapes that are likely to form. Such diagrams do not exist at present. Davison gives only the lift curves in his paper. There are lift and drag curves for several airfoil sections, which, when held vertically, resemble to a certain extent a cable with icicles. (See "Lift and Drag of Aerofoils Measured Over 360° Range of Incidence," Lock and Townsend, Reports and Memoranda of the Aeron. Res. Committee, No. 958, London 1914; also "Ergebnisse der Aerodyn. Versuchsanstalt zu Göttingen," Prandtl and Betz, v. 3, p. 78.) These

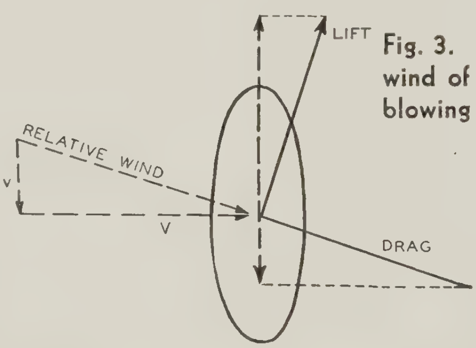


Fig. 3. Force diagram for wind of constant velocity blowing against a sleet covered cable

airfoil curves show several ranges of α where the $dL/d\alpha$ term is considerably greater than the D-term.

Taking Fig. 5 of Davison's paper, it can be calculated that the part of the driving force due to the $dL/d\alpha$ term is more than 20 per cent of the maximum inertia force of the cable during vibration. Though from this the damping force due to the D-term has to be subtracted, it is clear that the forces are of the right order of magnitude to explain the field observations.

Theory given so far is limited to small amplitudes, because the slope of the lift curve as well as the amount of drag were assumed to be constant. For large vibrations this ceases to be true; then it

becomes necessary to divide the path of motion of the conductor into several sections and to determine for each of these sections the driving force in much the same manner as in eq 2. Each of these forces has to be multiplied by the length of its respective path in order to obtain the work done. For small vibrations the work during one cycle will be positive, so that the motion will increase. For larger amplitudes, however, certain parts of the motion will have a negative driving force or damping. This occurs for instance, in Fig. 2 when α becomes $90° \pm 75°$, so as to penetrate into the region of positive slopes of the lift curve.

The final amplitude reached will be such that the total amount of work done during a cycle is zero. In an actual case, where there is additional damping in the towers, insulators, and other parts of the line, the amplitude will be somewhat smaller. This is so, assuming that all elements of the line have the same amplitude. In reality this is obviously not the case, so that the total work input by the wind has to be calculated for all elements of a span. Assuming that the span vibrates somewhat like a string, i. e., in a sinusoidal form, this calculation is a straightforward process involving no particular difficulties.

Related Phenomena

The combined effect of wind and sleet upon conductor vibration can be observed by means of a simple experiment. Take a stick of rectangular cross-section, a common yardstick for instance; hold one end in the hand and dip the other end vertically into a vessel of water. When the stick is pulled through with the narrow side in front, it is in the stable position, $\alpha = 0°$ of Fig. 2, and nothing will happen. When it is pulled with the broad side in front, however, $\alpha = 90°$, the condition is unstable. It will be found difficult to pull the stick through along a straight path; rather it will vibrate back and forth just like a sleet-covered transmission line conductor.

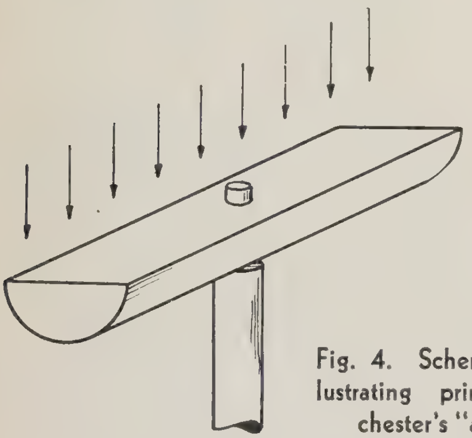


Fig. 4. Schematic diagram illustrating principle of Lanchester's "aerial tourbillion"

A toy, described and explained by Lanchester (see "Aerodynamics," London, 1907 and 1923, p. 45) and named by him the "aerial tourbillion," operates on the same principle (see Fig. 4). It consists of a stick of semi-circular cross-section that can turn about an axis. When it is held in the face of a strong wind and started rotating it will keep on doing so. The direction of rotation is immaterial; it will persist in whatever direction it is started. It is evident that the semi-circular section can be replaced by any cross-section which also would cause a transmission line to vibrate, and consequently would satisfy eq 3. If the bearing could be made without friction, this probably would be the easiest experiment by which the stability of various cross-sections could be tested.

A model which gives a striking illustration of the effect discussed is shown in Fig. 5. A piece of very light wood (balsa) of semi-circular cross-section (diam 2 in., length 12 in.) is suspended in 4 coil springs, making it a vibratory system. Great care was taken to reduce mechanical damping to a minimum, the whole device being mounted on a spring base. A common 10-in. desk fan blowing against the bar starts vibrations of increasing amplitude until after a minute or so the bar vibrates 4 in. up and down, closing the coils of the springs tightly on both sides. Bars of other cross-sections have been placed in this model, but since they are less sensitive than the semi-circular one, the desk fan was not sufficiently powerful. In the wind tunnel, however, a variety of sections has been excited in this manner.

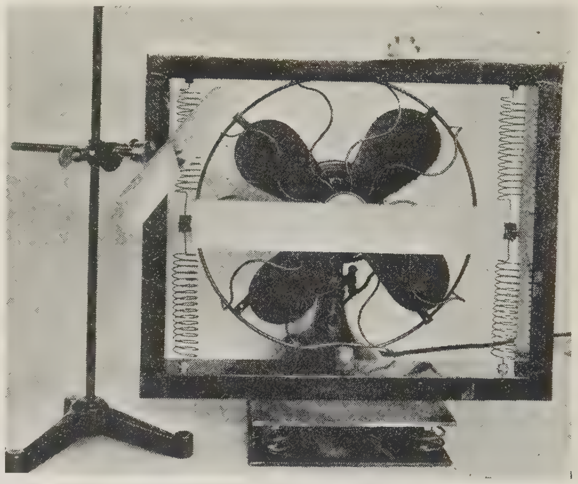


Fig. 5. Models for demonstrating the dynamic unstability of various cross-sections

Conclusions

Conclusions reached as a result of this study may be stated briefly as follows:

1. The slow vibrations of ice-coated transmission lines in a heavy wind can be explained as being caused by aerodynamic instability.
2. The phenomenon is entirely different from and has no connection with the rapid vibrations observed in fair weather at moderate wind velocities.
3. Instability occurs when the negative slope of the "lift curve" is greater than the amplitude of the "drag curve."
4. It follows from the theory that a change in the span length or in the tension of the cable does not affect the phenomenon.

Modern Steel Tower Transmission Lines

Some important requirements for modern steel tower transmission lines are presented in the following outline prepared by Group II of the A.I.E.E. subcommittee on steel transmission towers and conductors. This material is intended as a general guide to designers and is not a specification. Clearances, mechanical reliability, strength against lightning, and prevention of vibration, are considered.

IN THE design of steel tower transmission lines to meet present day demands for continuous service, many factors merit consideration. An outline of some of the most important of these factors has been prepared by Group II of the Institute's subcommittee on steel transmission towers and conductors. This outline should be of general interest to designers and operators of transmission lines as it is a summary of ideas which should be included in the transmission line to deliver the best of service. The statements are made with practically no explanation, as other works must be referred to for clarification, but in each case the statements have been carefully considered to emphasize a point that is important.

The factors to be considered are as follows:

A—Insulation and Clearances

1. Freedom from flashovers due to normal frequency disturbances such as are produced by partial failure of insulation, switching surges, system surges, etc.

2. Impulse flashover under assumed storm conditions and a temperature of approximately 120 deg F usually dictates clearances from conductor to tower, and conductor to ground wire. In the case of the ground wire the clearance at the middle of the span will depend upon very much higher surge voltages than those encountered at the tower; therefore the distance between the ground wires and line wires at the towers will be dictated by the clearances required at the middle of the span. Restricted clearance resulting from unusual mechanical loading conditions may result in flashover at normal frequency. The clearances for both normal frequency and impulse voltage should be determined in order to assure proper balance in design.

3. Freedom from interference to service produced by inadequate clearances from objects outside the right of way, on the right of way, crossing the right of way, or accidentally projected into the right of way, or by inadequate clearance between conductor and grounding objects.

Full text of an outline prepared by Group II of the steel transmission towers and conductors subcommittee of the A.I.E.E. power transmission and distribution committee.

Group II: L. L. Perry, *chairman;* F. E. Andrews, C. A. Booker, J. E. Clem, and C. L. Fortescue.

B—Mechanical Reliability

1. Freedom from mechanical interference with service produced by failure of towers, insulating elements, or conductors.

2. Ability to withstand the climatic loadings of wind and ice in the locality, or loading due to other conditions. In localities experiencing abnormal conditions, such as cyclones, consideration must be given the frequency of recurrence as well as the severity of the conditions imposed when determining the structural design.

3. In securing mechanical reliability it must be recognized that, although injurious corrosion should always be forestalled and prevented in the members of steel towers, the heavy steel sections may allow greater corrosion before the danger line is reached than light sections, provided the heavy members receive as good galvanizing coating as the light members.

4. The use of special conductor clamps or tower designs may limit the damage from broken conductors by preventing the failure of towers, and thus may allow quick and inexpensive repairs.

C—Strength Against Lightning

1. Freedom from lightning disturbances required by the standard of service desired. This is secured by adequate clearance of conductors from supporting structures and adjacent objects under storm conditions, by reduction in impulse voltage through provision of one or more overhead ground wires strategically placed, by adequate grounding of tower footings to assure footing resistances that are satisfactorily low, and by providing insulation adequate to prevent flashover up to the value of lightning potential that determines the limit of permissible outages.

2. The use of properly designed shielding rings will prevent damage to insulators or conductors from power currents following impulse flashover of the insulator string. However, modern high speed oil circuit breakers and relays that will clear a fault in a few cycles may on new lines equally well prevent dangerous conductor and insulator damage. Hence the use of shielding rings that will seldom function on lines well protected by ground wires may not be justified, due to the additional expense for the rings and for the tower structure suited thereto.

D—Prevention of Vibration and "Dancing" in Conductors

1. There have now been developed vibration dampers and reenforcing devices that experience so far indicates will provide practical protection against damage from vibration occurring at moderate wind velocities, characterized by rather high frequencies and relatively small amplitudes. Hence freedom from injurious vibration should be secured.

2. For the so-called "dancing" or "galloping" of conductors that is characterized by low frequencies, large amplitudes, and usually, though not always, the presence of some sleet, no known remedy has been found other than to prevent the formation of sleet when that is one of the factors. Freedom from interruptions produced by "dancing" would be better assured by as liberal a spacing of conductors and ground wires as economics permit.

E—Balanced Design

1. In designing to reduce interruptions from one type of hazard, such as lightning, the designer may increase the interruptions from some of the other hazards, such as accidental mechanical interference. For example, modern lightning studies indicate the advantage from the standpoint of better protection from lightning to be gained by increasing the height of the ground wires above the conductors. This height will depend upon the level of protection which is economically justified. However, by shortening the span lengths the same level of protection can be obtained with a great reduction in the height of ground wires above conductors. The net result of reducing the span is that the ground wires are lower, the overall height is lower, the cost of the individual tower is lower, but the total number of insulators is increased, and the numbers of towers and footings are increased.

2. The short span towers undoubtedly will resist as well as the long span towers, when designed on an equivalent basis, the usual and extraordinary loads due to service and weather conditions. Long span towers generally will be of heavier steel sections and therefore should more safely withstand accidental blows from foreign objects that may be projected against them for aeroplanes, dirigibles, and by blasting.

Non-Linear Circuits Applied to Relays

In this article are described applications of simple series and parallel non-linear electrical circuits to a-c voltage and current relays; such relays are characterized by great sensitivity. The special properties of the resonant-current relay make it especially adaptable for use as an undercurrent or undervoltage relay.

By
C. G. SUITS

General Elec. Co.,
Schenectady, N. Y.

PROPERTIES of certain non-linear circuits were described in a paper presented at the A.I.E.E. winter convention in 1931. (See A.I.E.E. TRANS., v. 50 ,1931, p. 724–36; ELEC. ENGG., v. 50, December 1931, p. 963–5.) Some of these circuits appeared to have properties which made them adaptable for use in voltage-sensitive relays. Development of these relays together with some theoretical considerations are treated in this article. The relays are characterized by great sensitivity to small changes in voltage and current, and have sturdy and economical mechanical elements.

Before describing the application to relays, the properties of saturating reactors in resonance circuits will be reviewed briefly. Consider first a reactor for which the effective current is related to the voltage in the manner shown by curve L of Fig. 1A, which was plotted from test data. For purposes of discussion, however, this reactor will be assumed to be greatly idealized so that (1) for sinusoidal applied voltage the current also is sinusoidal, and (2) the power losses are zero. These assumptions are highly impractical, but they can be demonstrated experimentally. Curve C of Fig. 1A shows the relation of the current to the voltage for a capacitance, similarly assumed to be free from losses. Given these 2 curves, the volt-ampere characteristics for these circuit elements in series and parallel combinations may be determined.

In a series combination (Fig. 1B), the current is identical in both elements. The difference in the ordinates of the 2 curves of Fig. 1A for any value of the abscissa is thus the voltage difference that must be supplied externally. If the current is plotted as a function of this externally applied voltage, the curve of Fig. 1B is obtained. Given these hypothetical circuit elements, the curve that actually would be obtained when they are connected in series would depend a great deal upon the type of voltage source employed, and in particular, upon the voltage regulation. For example, if the applied voltage is substantially independent of the load current, the curve shown by the solid line of Fig. 1B cannot be obtained, for as soon as point A is reached (for increasing voltage) the current will increase suddenly to the value C. The portion B-C-D of the volt-ampere curve thereafter will be traced for any subsequent increase or decrease of voltage, except when the applied voltage decreases to zero, whereupon the current will drop suddenly to zero from the value B.

It will be convenient to refer to the value of increasing voltage for which the current suddenly changes to a high value as the *resonant voltage.* Similarly the value of decreasing voltage for which the current suddenly decreases will be called the *dissonant voltage.* It is characteristic of both of these critical voltages that $di/de = \infty$.

A similar situation exists for these hypothetical circuit elements in parallel combination, except that the role of voltage and current is reversed. Thus, in Fig. 1C is shown the curve of voltage E, as a function of current I, similarly obtained from Fig. 1A. For this case the voltage changes suddenly at critical values of current. It will be convenient to refer to these critical values of current, for which the voltage suddenly increases or decreases as the *resonant current* and *dissonant current*, respectively, by analogy to the series circuit.

These series and parallel non-linear circuits thus are characterized by voltage sensitivity and current sensitivity, respectively, in the sense that for the critical regions a small change in voltage or current will result in a relatively large change in the dependent quantities. It may be seen that in these non-linear resonance circuits there is a similarity between the characteristic of current as a function of the voltage in the series circuit and voltage as a function of current for the parallel network. That is, if $I = f_1(E)$ is the characteristic of the series circuit, and $E = f_2(I)$ is the characteristic of the parallel circuit, f_1 and f_2 are similar functions.

It is possible to show that for these characteristics to be identical in form it is necessary that the cur-

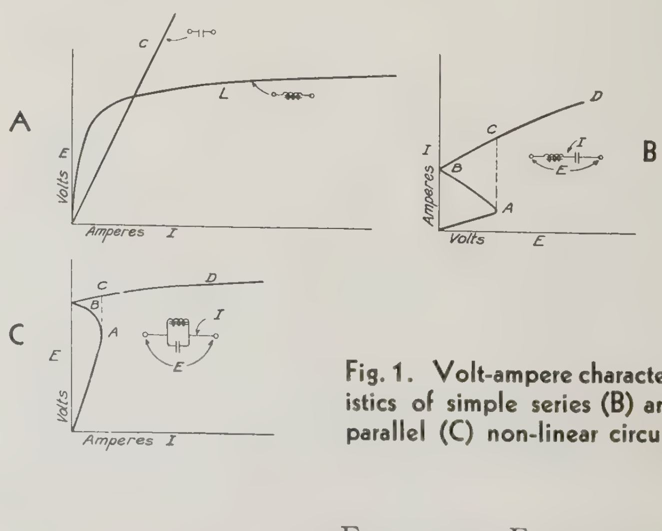


Fig. 1. Volt-ampere characteristics of simple series (B) and parallel (C) non-linear circuits

Based upon "New Applications of Non-Linear Circuits to Relay and Control Problems" (No. 32-85) presented at the A.I.E.E. summer convention, Cleveland, Ohio, June 20–24, 1932.

rent be related to the voltage in the inductance in the same manner that the voltage is related to the current in the capacitance. Thus, let i_L, e_L, i_c, and e_c, respectively, be the currents and voltages in the inductance and capacitance. Then, if $i_L = f(e_L)$ it is required that $e_c = f(i_c)$ where both of the f-functions are identical. It has been demonstrated that this theorem is true in general, and experimental results have been obtained which may be interpreted in the light of the theory.

Voltage sensitive and current sensitive a-c relays are important control elements in a modern electric power system. Their function is usually to determine when voltage control and current control apparatus should operate. These sensitive relays are used to pilot tap-changing transformers, induction voltage regulators, and motor driven rheostats; to place in a circuit or remove from a circuit ballast and protective resistances; to switch field circuits of generators; and to perform a great variety of similar functions. After they are required to be as accurate and reproducible in their characteristics as a laboratory voltmeter or ammeter and preferably to cost a fraction as much. Both series and parallel non-linear circuits have been applied to this problem of sensitive relays.

Fundamental advantages of relays employing resonant circuits follow directly from the large relative change in power at the critical current or voltage. This power may be supplied to a small load at an efficiency of the order 30 to 60 per cent in typical cases, and 85 per cent for the best cases. As a result of the large relative difference in power which is available, a sensitive relay may be made by controlling a relatively rugged and economical mechanical element by an electrically accurate circuit. Voltage sensitive and current sensitive relays of this general type appear to supply an important need in the field of industrial and supervisory control.

Voltage Relays

The critical change in current that follows from a small change in voltage has been shown in the curves of Fig. 1. By several means, the simplest of which requires an increase in circuit resistance, these curves, which are double-valued in voltage and current, may be changed to single-valued functions of these variables (see Fig. 2). It is found experimentally, and may be inferred from the graphical construction, that when resistance is varied, the *resonant voltage* experiences a negligible change, while the *dissonant voltage* changes by a relatively large amount. This property is susceptible to a simple calculation for almost-linear cases. For the present purpose it is sufficient to know that the dissonant voltage varies with R (Fig. 2), while the resonant voltage remains substantially constant.

It is found by experiment and may be inferred from the graphical construction that both the resonant voltage and dissonant voltage increase together as the number of turns on the reactor becomes greater.

There are several optional means of energizing a contactor mechanism from this non-linear series circuit. From what part of the non-linear circuit the load is energized in a practical case depends upon the characteristics of the contactor mechanism and its reaction upon the circuit. When this mechanism is a solenoid and armature (2-position, not "floating") the preferred position in the circuit is in parallel with the capacitance or in parallel with the capacitance and a portion of the inductance.

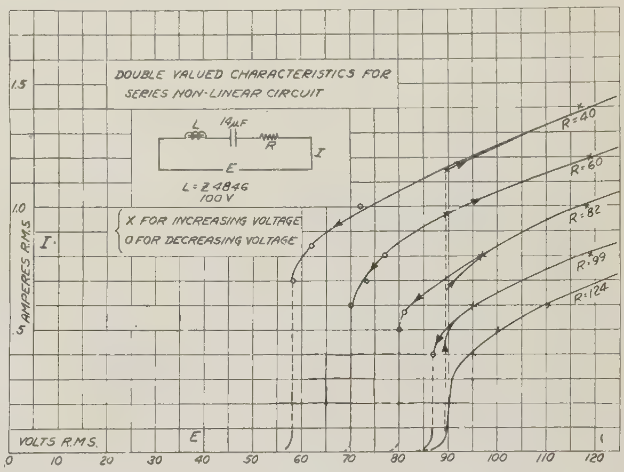


Fig. 2. Varying the resistance in the series non-linear circuit varies the "dissonant" voltage of the circuit, but does not affect appreciably the "resonant" voltage

In Fig. 3 is shown a resonant relay employing a solenoid and armature contactor mechanism energized in parallel with the capacitor of a series non-linear circuit. When used on a source of constant frequency this type of relay may be adjusted to a minimum difference between pick-up (resonant voltage) and release (dissonant voltage) of $^1/_4$ per cent, and may, by change in resistance alone, be adjusted to a maximum difference of 30 per cent referred to the pick-up value. The maximum power requirement is 6 watts at 12 va.

In general, for resonant relays of this type, adjustments of the difference between resonant and dissonant voltages is made by a change in resistance, while the voltage region in which they both lie is varied by taps on the windings of the reactor. These adjustments are not strictly independent, but they are found to be sufficiently so for small changes. Reactors used in these relays differ in no important respect from small bell-ringing transformers. Standard transformer steels are employed and conventional tolerances are found to be satisfactory. A relay of this kind is much more economical to build than any previously available device of the same accuracy and the same power controlling capacity.

It should be noted in particular that the high sensitivity of these relays does not depend upon the calibration of a spring or the accurate construction of the mechanical parts, but is fundamentally due to the electrical properties of a circuit which may reasonably be expected to remain constant over

long periods of time. Data available from life tests and service in the field bear out this conclusion.

Pick-up and release characteristics of this voltage relay are subject to variation with frequency. The frequency error is of the order 1 per cent in voltage for a 1 per cent change in frequency. Thus, for use on frequency controlled systems where a 0.1 per cent is a usual frequency variation and a 0.2 per cent may be regarded as a maximum, the change in relay characteristics from this cause alone will be a like order of magnitude.

Current Relays

A resonant voltage relay may be used as a current relay by energizing the former from the voltage drop produced by passing the current through an impedance element. However, the voltampere burden of this impedance must be large compared to the volt ampere requirements of the relay, so that this method is wasteful of apparatus, power, or both. In precisely the same manner in which the series non-linear circuit may be applied to voltage relays, the parallel circuit may be used for current relays. The useful property of the circuit for this purpose is shown by the curve of Fig. 1*C* and may be stated to be the large relative change in voltage across the parallel network in response to a small relative change of current in the parallel branch. This critical change in voltage may be used to energize a contactor mechanism as a load; this load may be placed (1) in series with the secondary branch, (2) in parallel with the inductance, (3) in parallel with the resistance, or (4) in parallel with the condenser. In general, it is required that the voltage across the current relay be a small fraction of the total voltage of the circuit in which it is used. This implies that the capacity of the condenser must be very great for typical cases in which many amperes are to be passed by the relay on 110- or 220-volt circuits.

In the present state of the art it is uneconomical to build low-voltage high-capacity condensers, so that a transformer must be used to perform this transformation. It is feasible, however, to use a winding on the saturating reactor for this purpose, so that no additional equipment is required. A relay employing this circuit is shown in Fig. 4. For this particular relay the difference between pick-up (resonant current) and release (dissonant current) may be adjusted between limits of 3 and 15 per cent. The resonant current and the dissonant current vary inversely as the number of turns on the saturating transformer. As in the voltage relay previously discussed, the percentage difference between the pick-up and release characteristics, and the magnitude of these constants, are thus separately adjustable. The total power input at the resonant current is of the order 6 watts at 6.5 va.

It may be seen from the curve of Fig. 1*C* that for this parallel non-linear circuit employing a closed core reactor, the voltage across the parallel network increases but little for a relatively large increase in current beyond the resonant value. This means that in practice a current relay which is rated at 5 amp pick-up will be subject to a continuous current of a great many times that value. The voltage applied to the condenser and to the contactor mechanism never greatly exceeds the value it has at the rated resonant current. The single requirement is that the primary winding of the saturating transformer must be built for whatever maximum current is anticipated. In the case of the relay of Fig. 4, the current may increase to 8 times the pick-up value before the condenser voltage becomes $1^1/_2$ times its value at resonant current. It is relatively simple to provide this margin of safety in the design of these units, so that the problem of undercurrent relaying is well met with this type of equipment. By use of a ballast resistance or reactance in series with the current relay an undervoltage relay is produced. This type of relay is capable of tolerating continuous voltages greatly in excess of the actuating voltage.

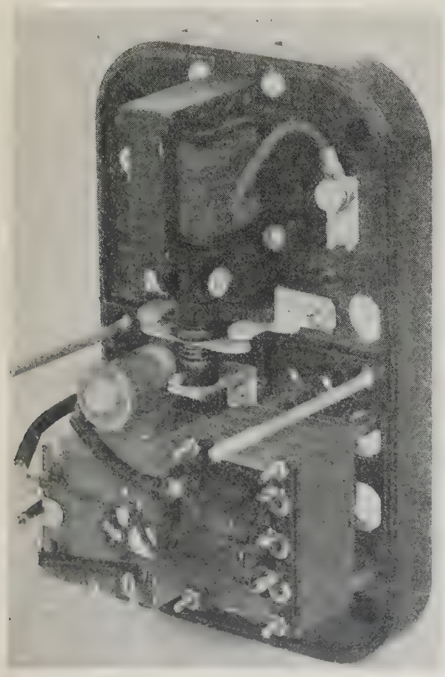


Fig. 3. (Left) A resonant relay employing a series non-linear circuit

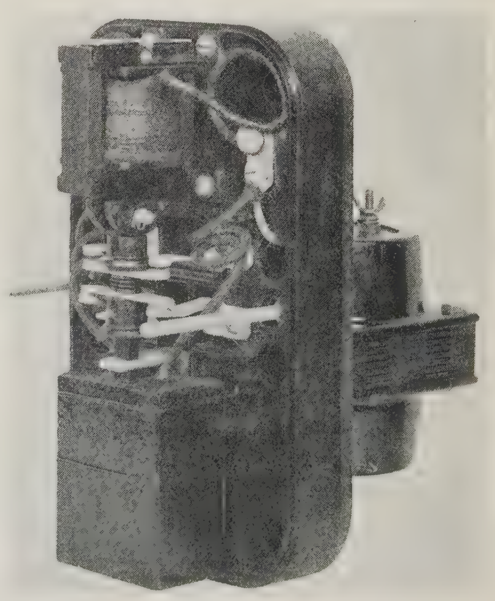


Fig. 4. (Right) A resonant-current relay employing a parallel non-linear circuit

Some New Ideas in Circuit Breaker Design

By
C. A. CHURCH
ENROLLED STUDENT A.I.E.E.

N. R. DAMON

Senior Students (1931)
University of Colorado,
Boulder, Colo

IN THE LIGHT of the present trends that are influencing the design, application, and operation of circuit breakers in electric power systems it seems reasonable to expect that the satisfactory circuit breaker of the future must have the ability to interrupt, in a few cycles and with minimum arcing, a circuit carrying a large load, and do this effectively without the use of oil. In the course of electrical engineering work at the University of Colorado, the authors developed 2 circuit breaker designs which show possibilities of incorporating the several desirable features requisite in a satisfactory circuit breaker. One design is an air-stream circuit breaker operating with compressed air, the other a vapor-blast circuit breaker operating with the use of ordinary water.

Before proceeding further, the characteristics of a power arc will be summarized briefly and the most effective methods of extinguishing it will be mentioned. During the time that an arc is sustained there are highly ionized, highly conductive gases of vapors occupying the arc space. The free electrons present in the conductive medium are emitted both by the gas within the arc space and by the heated contactors. Although the power current passes through zero twice in each cycle, the arc space loses its conductive properties so slowly that the recovery voltage readily maintains the arc. To support the arc therefore it is necessary to apply some external means of rapidly lowering the conductivity of the arc gap. Among the several ways of expediting this deionizing process are: (1) increasing the pressure, (2) rapidly cooling the contactors and arc space, (3) binding the free electrons so as to render them ineffective as current carriers, and (4) completely removing the ionized gas, replacing it with a medium of high dielectric strength. With the application of one or more of these physical processes the arc is readily quenched. One or more of these artificial means of increasing the dielectric strength of the arc space were employed in the 2 breaker designs previously mentioned.

The operation of the air-stream circuit breaker is revealed in principle by the sketch shown in Fig. 1. In this design, as the circuit breaker is tripped a blast of compressed air operates to lengthen the arc to the natural breaking point, and also to remove ionized gases from the arcing chamber. Further, the air blast serves the important purpose of cooling the electrode and cooling the arc itself as it extends. A crude test model of this breaker, made out of an ordinary 4-in. 4-way cast iron pipe fitting and tested in the university laboratory, operated successfully in spite of the poor way in which it represented the theoretical design. With ordinary wood serving as insulating bushings, with brass contactors having a maximum stroke of 3 in., and with an over-all size of

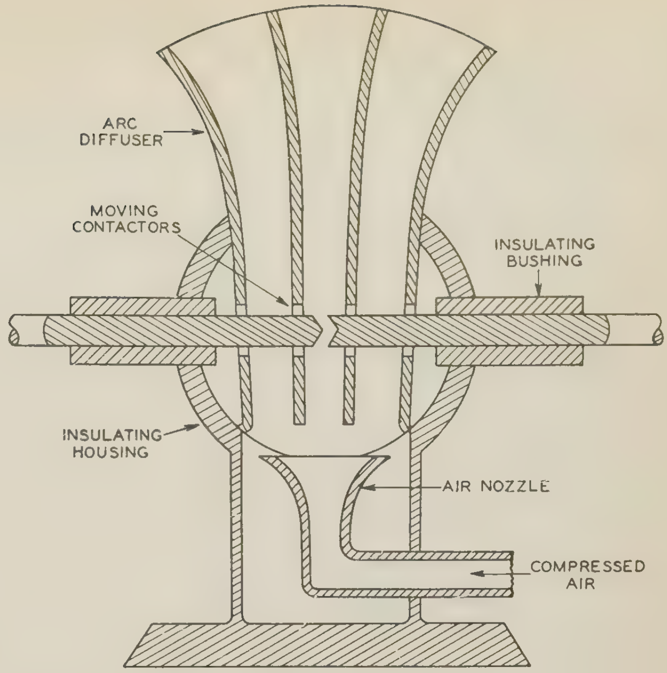


Fig. 1. Schematic design for proposed air-stream circuit breaker

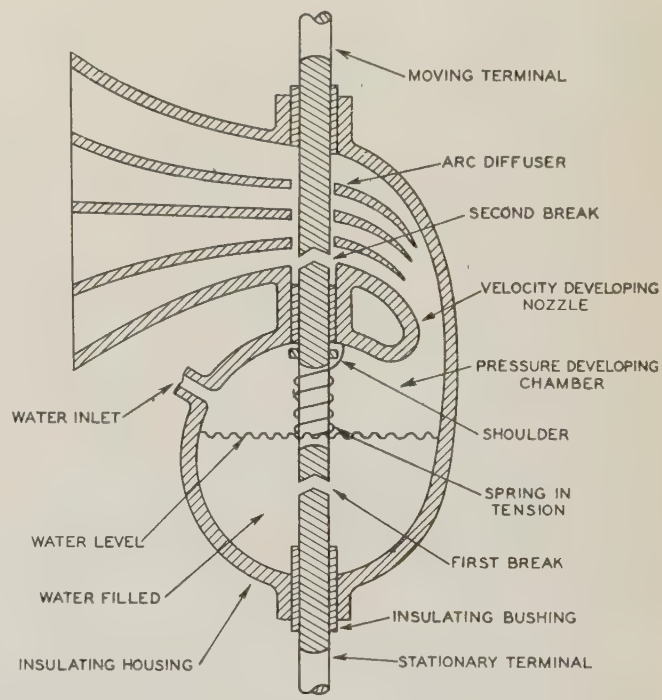


Fig. 2. Schematic design for proposed steam-blast circuit breaker

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Abstracted from the manuscript "New Ideas for High Voltage Circuit Breakers" presented April 24, 1931, at a joint meeting of the Denver Section and the University of Colorado Branch; awarded the A.I.E.E. prize as the best 1931 Branch paper from the A.I.E.E. North Central District. *Not published in pamphlet form.*

11x12x5 in., the test model successfully interrupted in the third half-cycle a 2.3-kv 240-kva short circuit in a highly inductive circuit.

In addition to the investigation of the air-stream breaker as outlined, the authors' investigations led to the experimental design of a so-called vapor-blast circuit breaker. This breaker has ideal theoretical features and some seemingly attractive possibilities. The fundamental principle of this design includes also the lengthening of the arc and deionizing of the arc space, but accomplishes that result by means of a steam blast rather than an air blast. The theoretical design is indicated in the sketch in Fig. 2. In principle, as the breaker is tripped the lower contacts open, establishing an arc just beneath the surface of a relatively small quantity of water, rapidly vaporizing that water. As the breaker travel increases the upper or secondary break occurs, establishing an arc in the deionizing arc chambers as indicated. The blast of vapor from the lower chamber then operates to extinguish the arc in the upper chambers.

A crude model of this breaker, made up of 2 2-in. 4-way iron pipe fittings with a 1-in. pipe forming the connecting port, was tested under short circuit conditions similar to those mentioned for the air blast breaker, and successfully interrupted 240 kva at 2.3 kv in the sixth half-cycle. The breaker operated so quietly that it was impossible to tell whether or not the circuit had been interrupted except for a streak of greenish flame appearing for an instant at the exhaust opening, and for the fact that the back-up fuses installed for secondary protection did not blow. This unit likewise was exceedingly compact in its design.

Of course, tests would have to be made at much higher voltages and much heavier loads to determine the practicability of these designs. However, judging from the satisfactory operation on 2.3 kv, and after studying the operation of new circuit breakers made by the larger manufacturing companies in America and Europe, the authors believe that they have feasible possibilities.

A High Speed Reactance Relay

A high speed relay for the protection of transmission lines has been developed which uses the induction dynamometer principle for the production of torque. This relay operates on the reactance principle. Details of the relay and its operating characteristics are presented herewith.

By
A. R. VAN C. WARRINGTON General Elec. Co., Philadelphia, Pa.
ASSOCIATE A.I.E.E.

MAINTENANCE of stability on modern interconnected high capacity transmission systems is made considerably easier by the use of relays which not only operate extremely rapidly on line faults, especially 3-phase short circuits, but refrain from operating on the surges of power which often follow the interruption of the fault current. A new distance relay has been developed which operates in the order of one cycle, even on low voltage, and employs reactance as a basis of distance measurement, thereby being free from errors due to the variable resistance of the fault itself.

The reactance principle is now generally acknowledged to be the logical basis for distance measurement, even for high speed relays. The initial voltage in an arcing fault may be only about 5 per cent of system voltage, but on faults occurring near the end of the protected section tripping is delayed somewhat in order to maintain selectivity with the breaker in the next section. During this delay, which is generally of the order of a $^1/_2$ sec, an arc between conductors of a transmission line

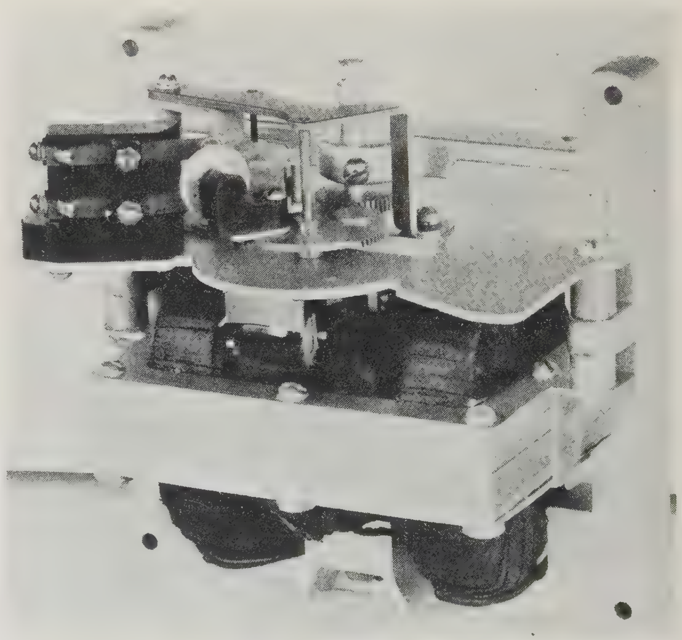


Fig. 1. Induction dynamometer unit

Based upon "A New High-Speed Reactance Relay" (No. 32M12) presented at the A.I.E.E. summer convention, Cleveland, Ohio, June 20–24, 1932.

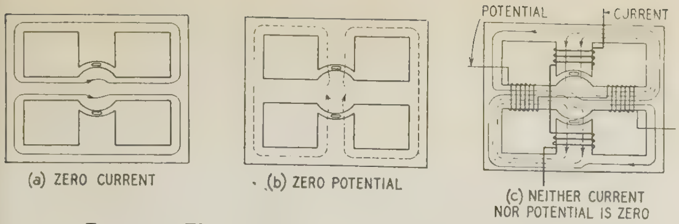
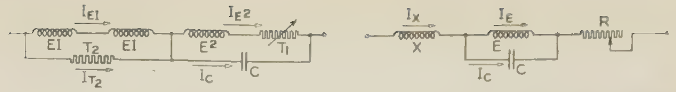


Fig. 2. Flux paths in induction dynamometer



(a) Ohm unit potential circuit
X = reactor
E = potential winding
C = capacitor
R = variable resistor

(b) Starting unit potential circuit
EI = directional potential coil
E² = restraining potential coil
T = thyrite resistor
C = capacitor

Fig. 4. Potential circuit connections for ohm unit (left) and starting unit (right)

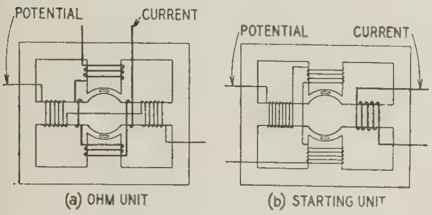


Fig. 3. Connections of coils

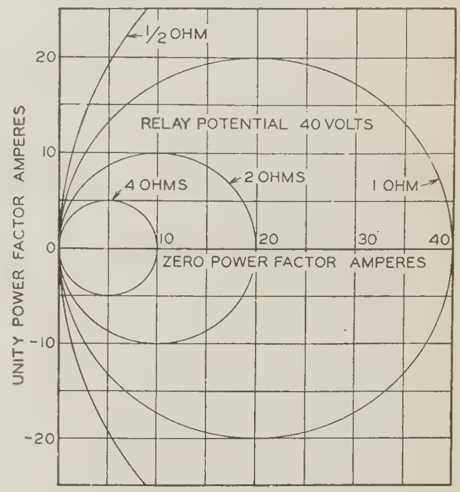


Fig. 5. Ohm unit operating characteristics

Ohm unit operates for values outside the circles

has time to stretch considerably in the presence of wind and, in many cases, to increase its impedance so that an impedance relay will fail to operate. The shorter the section the greater is the chance of failure.

The new relay is operated by motor units of the induction dynamometer type and consequently produces many times the torque per unit of electrical input that could be obtained with the induction disk or plunger type of relay. The distance measurement is carried out by 2 reactance-ohm units, one set to operate on faults within a zone reaching nearly to the end of the protected line and the other given a higher setting reaching out well into the neighboring section for which back-up protection is desirable. Faults are distinguished from surge and load conditions by a starting unit which is a very sensitive directional relay having a voltage restraint which gives it an ohmic characteristic; at normal voltage the starting unit has maximum torque on currents lagging 90 deg behind the line voltage. A timing unit also is provided.

The Induction Dynamometer Principle

The principles underlying the production of torque in the electric motor or dynamometer are well known. In the induction dynamometer, torque is generated in the same way, but instead of leading the current into the moving conductor by wires or through a commutator, it is induced by transformer action, as shown in the diagrammatic sketch, Fig. 2. Eliminating the lead-in wires simplifies the problem of insulation and, with proper design, results in a simple, efficient, and sturdy device.

The application of the induction dynamometer principle to relays is by no means new. The advantages of this construction for instantaneous relays have been known for many years, but, until the recent need for extremely rapid operation, the induction disk construction has been found satisfactory and is of course ideal where an inverse time characteristic can be used.

The shielded and balanced construction used in the present relay is illustrated in Figs. 1 and 2. This relay can be used for obtaining a pure directional characteristic, i. e., free from the effects of inductive coupling between the current and potential windings, or this coupling can be introduced purposely to obtain other characteristics. The directional torque is a function of the product EI, and the torques caused by interaction between the 2 circuits are functions of I^2 and E^2. In this design either of these "square" torques may be eliminated and the other controlled down to zero.

In the ohm unit the I^2 torque is not undesirable and is not eliminated but is used to advantage as a factory adjustment and controlled by the starting position of the inductor ring, the main adjustment (for the reactance setting) being made with a rheostat in the potential circuit. The compensating I^2 torque is derived from the phase splitting action of the inductor ring in the current flux. Figure 2 (*c*) shows how part of the current flux threads the ring and the rest does not. The relative magnitudes of those components of the current flux which thread the ring and those which avoid it are controlled by the position of the ring and in turn control the I^2 torque. The I^2 torque is further controlled by the phase angle between these 2 components of the current flux which is determined by the power-factor of the ring and of the potential circuit with which it is inductively coupled. The power-factor relationship is arranged to give the most efficient operation.

On the other hand the E^2 torque is undesirable in an ohm unit. If this is not removed the ohm unit will have torque on potential alone and the characteristic circle will be changed (see Fig. 8). If this potential bias tends to close the contacts it obviously will be very undesirable. If it tends to open the contacts it will increase the radius of the circle so that it approaches an impedance characteristic. Any departure from pure reactance not only makes

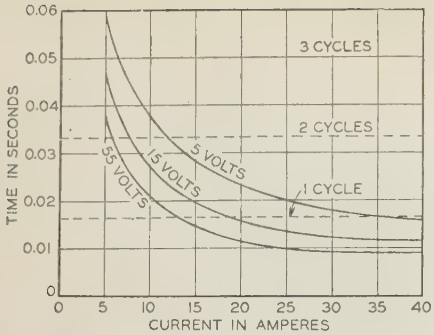


Fig. 6. Time-current curves of starting unit

Current at 50 per cent lagging power factor

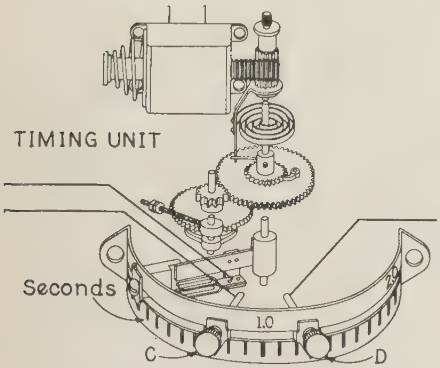


Fig. 7. Schematic diagram of timing unit

the ohmic measurement susceptible to error with arcing faults but the mixed impedance-reactance characteristic makes the setting of the relay very complicated. To avoid both of these undesirable qualities the ohm unit herein described has been designed expressly to eliminate all E^2 torque in order that a pure reactance characteristic might be obtained.

In the starting unit extra E^2 troque caused by the coupling between the windings is also not undesirable if under control because a voltage restraining torque is required, and in this case the I^2 torque is not required. The position of the ring controls the extra E^2 torque and again provides a factory adjustment for controlling the current pick-up of the unit, the main adjustment being through the medium of taps on the current coils.

On the other hand the I^2 torque is undesirable in a starting unit because at high currents and low voltages the directional properties of the unit would be lost when the I^2 torque was comparable to the EI sin ϕ torque, where ϕ is the power-factor angle of the protected circuit. Consequently the power-factor of the potential circuit is arranged so that any current induced in the potential circuit by the current flux is at a phase angle which produces no torque.

The Ohm Unit

The torque of the unit is proportional to EI cos $(\phi\text{-}\theta)$, where θ is the angle between E and I at which maximum torque is obtained. By proportioning the resistance and reactance in the potential circuit so as to make the internal angle θ = 90 deg, the torque becomes proportional to EI sin ϕ, the reactive power flowing in the protected circuit. By providing an additional current winding, as shown in Fig. 3(a), a torque proportional to the square of the currents is obtained, and by properly arranging the polarity of the 2 current windings, the unit is caused to close its contacts when $KI^2 > EI \sin \varphi$, or when $\frac{EI \sin \varphi}{I^2} < K$, i. e., when the reactance measured by the unit falls below the critical value, K.

The ohmic adjustment is made with a slide wire rheostat according to the secondary reactance of the protected section of line. This rheostat is wound with wire of negligible temperature coefficient and graded in size so that uniform accuracy of setting is obtainable over the whole scale.

The Starting Unit

Distance relays of both the impedance and reactance types require an additional unit to give them a directional sense in order to confine their operation to the protected section. By including voltage restraint in the characteristic of the directional unit, the distance relay can be made to discriminate between short-circuit and surge currents. This discrimination is increased by arranging the directional torque to be a maximum at a highly lagging angle.

The starting unit is similar in construction to the ohm unit except that the current coils on the 2 poles are replaced by the directional potential coils. This potential winding is connected in the same position in the potential circuit as the reactor in the ohm unit (see Fig. 4(b)); and there is a special resistor connected in series with the restraining potential coils on the middle iron. The theory underlying the operation of this circuit has been described in "Modern Requirements for Protective Relays on Important System Interconnections," by O. C. Traver and L. F. Kennedy, A.I.E.E. Trans., v. 49, 1930, p. 1226–31.

As in the ohm unit, the flux threading the inductor ring is derived from potential and current coils wound in opposition, and the current induced in the ring is a function of $I-E$. This current, reacting with the potential flux in the air-gaps creates a torque proportional to EI cos $(\phi\text{-}\theta) - KE^2$, so that the starting unit picks up when $\frac{E^2}{EI \cos (\phi\text{-}\theta)}$ is less than a desired value.

The condenser C across the restraining potential winding, E^2, causes θ to be 90 deg at normal voltage. The special resistor T_1, known as thyrite, has a characteristic $I = KV^n$ where n is about 3.5. Due to this characteristic it causes the restraining torque E^2 to be a maximum at normal voltage and to drop off rapidly as the voltage is reduced. Another similar resistor T_2 connected across the directional winding EI causes the driving torque to be amplified and the angle θ to decrease as the voltage is reduced. These characteristics enable the starting unit to pick up on short-circuit currents of small magnitude while preventing it from operating on overload or surge currents; furthermore they enable the relay to operate rapidly even with an arcing fault close to the bus. Taps are provided on the current coil which enable the minimum pick-up current at 115 volts to be adjusted at 8, 12, or 16 amp.

The Timing Unit

The timing unit, shown in Fig. 7, consists of a clockwork mechanism controlled by an escapement and operated by means of a d-c solenoid, also shown. The time arm sweeps the scale at a uniform rate and makes a passing contact at the first stationary (intermediate) contact mounted on the time scale, going to the second (back-up) stationary contact only in emergency. The function of the timing unit is to allow tripping of the circuit breaker up to a higher ohmic value and after a suitable time delay if the fault is not near enough to warrant instantaneous tripping; and further to trip after a maximum time interval in case of emergency.

Operation

Upon the occurrence of a fault within the protected zone the starting unit operates, completing the negative end of the tripping circuits, and starting the timing unit. If the fault is well within the protected section a first (low-set) ohm unit closes its contacts and immediately trips the circuit breakers. This ohm unit covers not more than 90 per cent of the protected section. If the fault is beyond this range the ohm unit does not trip and, at the end of an adjustable period depending on the speed of the breaker, the timing unit connects in the trip circuit a second ohm unit with a higher ohmic setting corresponding to a point well beyond the end of the protected section but not beyond the instantaneous zone of the next relay.

If the fault is still more remote but is not beyond the range over which back-up protection is considered desirable the ohm unit will once more refrain from operating and the timing unit will close a second contact, after a further adjustable period (back-up time) and trip the circuit breaker directly. Targets indicate whether the relay has operated instantaneously or in intermediate or back-up time.

The starting unit will hold its contacts open if the voltage is entirely removed due to accidental or other causes. If the voltage is accidentally reduced to a value above zero, such as by the blowing of a potential fuse, the restraining springs on the ohm unit can be tightened so as to prevent operation below a desired value of load current. The starting unit can be relied upon to prevent tripping on leading currents which would operate the ohm unit.

This adjustment, however, only provides a limited degree of protection against such operation, because the relay cannot be expected to differentiate between conditions of current, voltage, and phase angle which at one time may represent a line fault and at another time may represent an emergency where tripping is undesirable.

The minimum time of a distance relay is necessarily dependent upon the speed of its directional unit. The highest speed is often desired when the voltage is lowest. Three phase short circuits, where the greatest speed is necessary on account of stability, presented a difficult problem since all 3 phases may have low voltage, and it is therefore of no avail to use the potential from another phase. In this relay the problem is solved by the special characteristics of the potential circuit, previously described in this article. With this arrangement the starting unit has the following characteristics:

1. With constant current the directional torque per volt increases as the voltage is reduced while the restraining torque per volt decreases.

2. At normal voltage the minimum pick-up is with current lagging the voltage by 90 deg; as the voltage is reduced this angle is reduced until at 10 per cent of normal voltage maximum torque occurs at 60 deg lagging.

The advantages of this design of starting unit can be summarized as follows:

1. Maximum protection against undesirable operation during heavy surges of power between generating sources.

2. Maximum response to fault currents, i. e., maximum directional sensitivity only present when required; namely, at low voltage. This is accomplished without the use of contacts and without excessive burden at any potential, normal or below.

3. Extremely rapid action obtained even at low voltages with sturdy relay parts and with normal travels and contact pressures.

Reactance Relay on Surge Conditions

An oscillation between 2 interconnected systems or generating plants may occur when a large load is switched in or out, or when a fault occurs near one of the stations. During such an oscillation, when the internal emf vectors of the 2 sources of power are furthest apart, the voltage at any point on the interconnection will be subnormal and the current may be several times normal. From the ohmic point of view this condition represents a fault. However, operation of a relay is undesirable unless the machines are in danger of going out of step. In the reactance relay, operation is guarded against

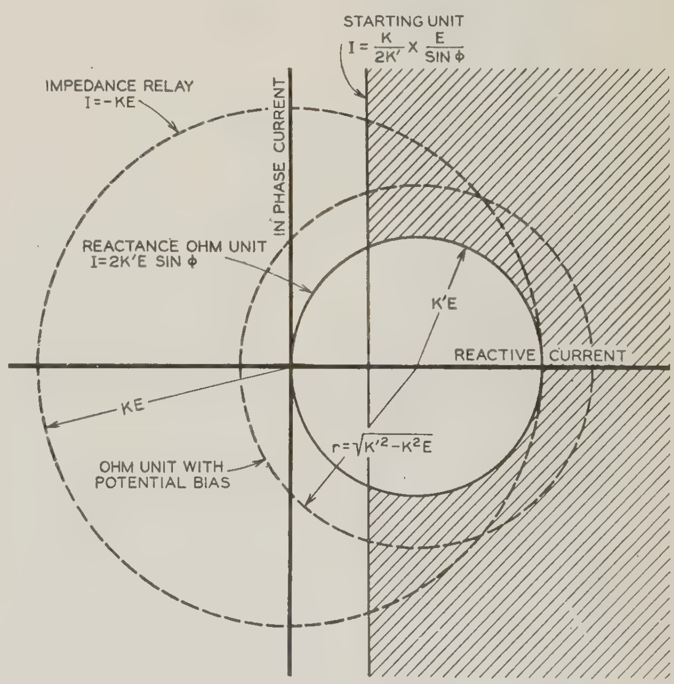


Fig. 8. Distance relay current characteristics

Reactance relay trips for currents within shaded area. General equation for the above characteristics (where θ = 90 deg) is $I^2 + KE^2 - 2K'EI \sin\varphi = 0$

by using power factor as well as impedance as a basis of distinction.

Since 90 deg is the angle between the internal emfs of the 2 power sources where the maximum synchronizing torque occurs, it is safe to assume that swings to more than 120 deg are in dangerous territory because, owing to the decreasing synchronizing torque, there is little to prevent them from swinging on out of step. With 120 deg between the internal emfs the voltage in the electrical center of the interconnection would be 50 per cent and would be higher at other points. The power factor of the surge current at this point would be cos $(90° - \phi)$ where cos ϕ is the power factor of the line, and would be near unity.

In this reactance relay the starting unit has minimum pick-up at normal voltage when the current lags the voltage by 90 deg. The pick-up near unity power factor is therefore very high even at 50 per cent voltage. The power factor of the surge current at any point on the interconnection is high enough to make operation of these relays a remote possibility.

In addition to the power-factor distinction the starting unit is further aided in discriminating between surges and faults by the fact that maximum sensitivity of the *EI* magnet occurs only at low voltages. Since power swings involve voltages between 50 per cent and 100 per cent of normal and since faults generally make the voltage at the relay less than 50 per cent this characteristic makes the relay still more selective between fault and surge conditions.

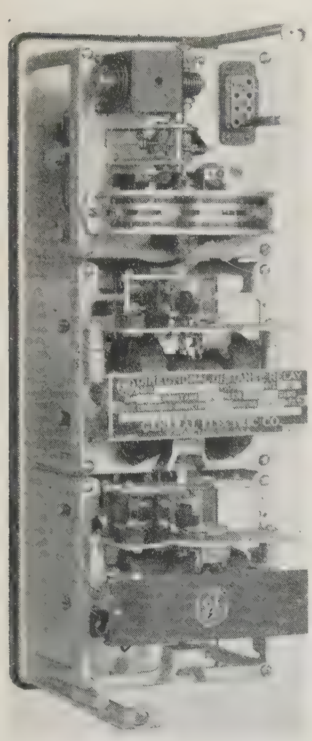


Fig. 9. Induction dynamometer reactance relay with 2 time steps

Relay Connections

In each ohm unit of the relay there are 2 current circuits, *A* and *B*. For most systems the 2 circuits are connected in series to the current transformers. In cases where the instantaneous zone is required to extend as nearly as possible to the end of the protected section a different connection may be necessary to compensate for variations in distance measurement due to system conditions. For instance, if the inherent power-factor angle of the line is more than 60 deg lagging 3 phase short circuits will appear in the relay to be nearer than phase-to-phase short circuits. In cases where the inherent power factor is more than 70 deg lagging it is advisable to connect circuit *A* to the current transformer in the phase lagging the phase in which the circuit *B* is connected. Where the relay is used for protection against single-phase-to-ground faults and where the secondary reactance varies appreciably with system conditions (see "Fundamental Basis for Distance Relaying," by W. A. Lewis and L. S. Tippett, Electrical Engineering, June 1931, p. 420–2), the circuit *A* should be connected in the residual circuit of the current transformers, through an auto-transformer whose ratio depends on the number and nature of the ground wires on the line. If there are no ground wires (or one steel wire) the auto-transformer can sometimes be eliminated.

This arrangement of the current coils permits the usual star-connection of the current transformers in all cases. This is an advantage because the same current transformers are often used for both phase and ground relays and the residual current cannot be obtained if the current transformers are delta connected. Furthermore, the extra burden imposed by auxiliary star-delta current transformers is avoided.

Protection Against Ground Faults

On systems where compensation for system and fault conditions is not required and where, as mentioned above, the current from the current transformer in one phase can be used directly, the same relay can be used for protection against all types of faults on the transmission line. In this case the relay supplied with current from phase 1 is normally connected to delta potential V_{12}. Upon the occurrence of a single-phase-to-ground fault one end of the potential circuit is transferred to the neutral so that relay is now supplied with the star voltage V_1. This transfer is effected by a discriminating relay which does not respond to faults involving more than one phase.

In cases where system conditions necessitate compensation for the variations in secondary phase-to-ground reactance the ohm unit circuit is duplicated for the 2 types of faults. The ohm unit responsive to faults involving more than one phase is supplied with delta voltage and with currents from the 2 corresponding current transformers. The ohm unit responsive to single-phase-to-ground faults is supplied with star voltage and with currents from the corresponding current transformer and from the residual circuit.

Summary

The advantages of this relay may be summarized briefly as follows:

1. The reactance principle is the logical basis for distance measurement on transmission lines.

2. The new reactance relay employs a simple sturdy construction having only a single electromagnetic element per unit with windings arranged to detect faults or to measure reactance.

3. The balanced and shielded construction used in the ohmic elements results in improved characteristics as well as increased speed and economy in voltampere burden.

The Parallel Type of Inverter

Among the many interesting and valuable applications of that versatile device, the 3-electrode hot-cathode gas-filled thermionic tube, is the inverter. Of the several different types of circuits developed, the "parallel" type gives promise of becoming of some importance, and already has been used commercially for supplying power to a-c radio sets from d-c systems. This article gives an analysis of the operation of this type of inverter under different load conditions.

By
FREDERICK N. TOMPKINS
MEMBER A.I.E.E.
Brown University,
Providence, R. I.

AMONG the many interesting and valuable applications of the 3-element hot-cathode gas-filled thermionic tube is the inverter. Its purpose is the inversion or changing of direct current to alternating current, the reverse process of the more usual rectification. While this inversion process has been possible with 3-element vacuum tubes, their low efficiency and high voltage drop has prevented their practical use for this purpose. The gas filled tube, with its high efficiency and low voltage drop has made the circuit practicable for reasonable amounts of power.

Although the nomenclature concerning inverter circuits is still in a state of flux, in general they have been divided into 2 main types, called "series" and "parallel." Considerable data have been published and many circuits devised for the former type, but little more than the fundamental circuit has been given for the latter. It may be of interest to present the results of an investigation of the parallel type, undertaken for the purpose of a better understanding of the function of each part and of the operation of the circuit as a whole.

Characteristics of the tubes available commercially for this application are given in the bulletins of the manufacturers. Their operation differs greatly from that of a vacuum tube. Because of the gas content, ionization is present whenever current flows thus preventing the existence of a space-charge with its consequent high potential drop. The grid of a vacuum tube has complete control of its operation; the grid of a gas filled tube can control only the starting of current flow but not its stopping. The circuit must be arranged to provide the stopping action.

The gas filled tube is inherently a rectifier, passing current in one direction only; thus it is often convenient to think of the device as a one-way contactor with an average potential drop of 15 volts irrespective of the amount of current. This view will help in understanding the operation of the inverter.

Fundamental Circuit

Development of the inverter from simple circuits involving gas-filled tubes operated by direct current has been described by several writers on the subject and will not be undertaken here. The final circuit of the type studied is given in Fig. 1. Direct current is supplied as indicated, each tube passing current alternately in opposite directions through the halves of the transformer primary winding, thus inducing alternating current in the output circuit. Commutation, that is, the act of stopping conduction in one tube and starting it in the other, is provided by the action of the capacitor in the circuit. The frequency of the output is determined by the frequency applied to the grid transformer, which in this case is shown supplied from an external circuit. It is possible to make the circuit self-exciting, in which case the frequency is governed by the constants of the grid circuit.

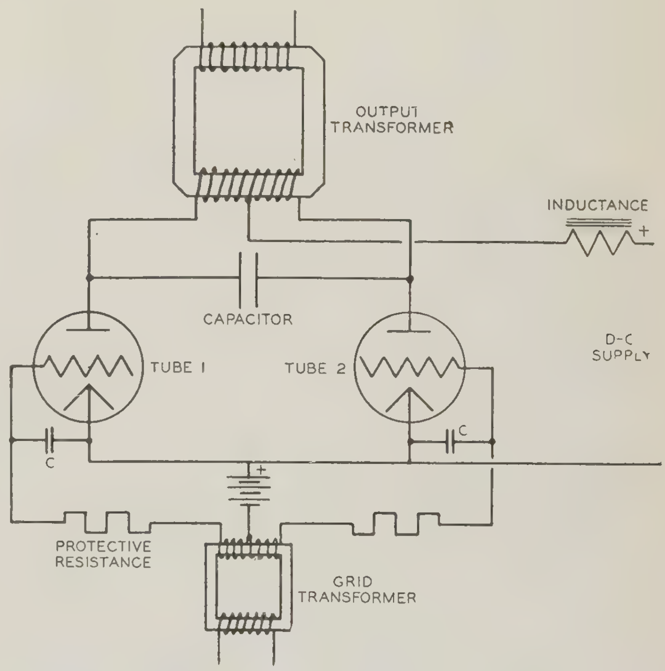


Fig. 1. Fundamental circuit of the parallel type of inverter

Recently other investigators have determined that the voltage of the grid tends to follow that of the

Based upon "A Parallel Type Inverter" (A.I.E.E. Trans., v. 51, 1932, p. 707–14) presented at the A.I.E.E. North Eastern District meeting, Providence, R. I., May 4–7, 1932; contains additional information made available after the original paper was prepared. *Not published in pamphlet form.*

anode (see "Grid-Controlled Mercury Arc Rectifiers," by H. D. Brown, *G. E. Rev.*, v. 35, Aug. 1932). Peaked grid-voltage waves are suggested as a means of preventing this, thus making the operation more stable. Waves of this nature may be secured by the use of special peaked-wave transformers (see "Transformers With Peaked Waves," by O. Kiltie, Elec. Engg., v. 51, Nov. 1932, p. 802–4) or by the use of copper-oxide rectifiers in the grid circuit (see article by H. D. Brown, *loc cit*). Direct current impulses applied to the grids through synchronously operated contacts also can be used (see "Mercury Arc Rectifier Applied to A-C Railway Electrification," by O. K. Marti, A.I.E.E. Trans., v. 51, 1932, p. 659–68).

Operation

The sequence of events in the operation of the circuit is illustrated by the oscillograms of Fig. 2, which give the voltages and currents in the different parts at approximately full load and unity power factor. In the tests herein described General Electric type *FG*-67 thyratron tubes were used, the condenser capacity being 4.5 μf, the inductance 0.2 h, and the applied voltage of the order of 500 volts. While with this applied voltage the peak inverse and peak forward voltages were, under some conditions, rather more than the values given in the tube rating, no trouble was experienced from this cause. Circuit constants were chosen after much experimentation to give the best output wave form under widely varying conditions of load regardless of other factors such as regulation. In taking the oscillograms the input voltage was adjusted until the output voltage was 110 volts, the grid voltage frequency being 60 cycles. The connection diagrams associated with the oscillograms of Fig. 2 show the positions of the oscillograph galvanometer elements in the circuit, and the various curves are numbered accordingly both in Fig. 2 and in Figs. 3, 4, and 5. The results are purely qualitative as no attempt was made to calibrate the elements.

It now may be of interest to analyze the conditions in each part of the circuit step by step throughout the cycle of operation. Referring to Fig. 2 at time *A*, curve 1 shows that the grid potential was zero, which at the applied plate potential was sufficient to permit the plate current to start as shown in curve 2. The condenser immediately charges through half of the transformer primary winding as shown in curves 3 and 4. The current in this half would have become zero except for this charging current. Current in the other half of the primary winding, which was slightly negative, becomes positive as shown in curve 5. A high potential difference between the anode and cathode of the tube drops to a low value as soon as the current starts, as shown by curve 7, the anode being positive. This tube voltage drop of between 10 and 24 volts does not show on the oscillograms as the scale required by the inverse voltage was too large. Curves 8, 9, 10, and 11 are the voltages of the halves of the transformer primary, the whole primary, and the secondary windings, respectively. Curve 12 shows the output current which, when compared with the voltage of curve 11, shows that the load was noninductive.

At time *B* the transformer primary and secondary voltages and the output current are zero. Comparing these with curve 2 indicates that this condition does not exist until some time after the current through the tube has started, thus showing that the latter leads the induced voltages. This is a characteristic of this type of inverter that will be found throughout its operation; it is the function of the condenser in the circuit to provide this phase relation. It will be shown later that when the power factor of the load is sufficiently leading, the condenser no longer is needed, the necessary phase relations for inverter operation being caused by the load.

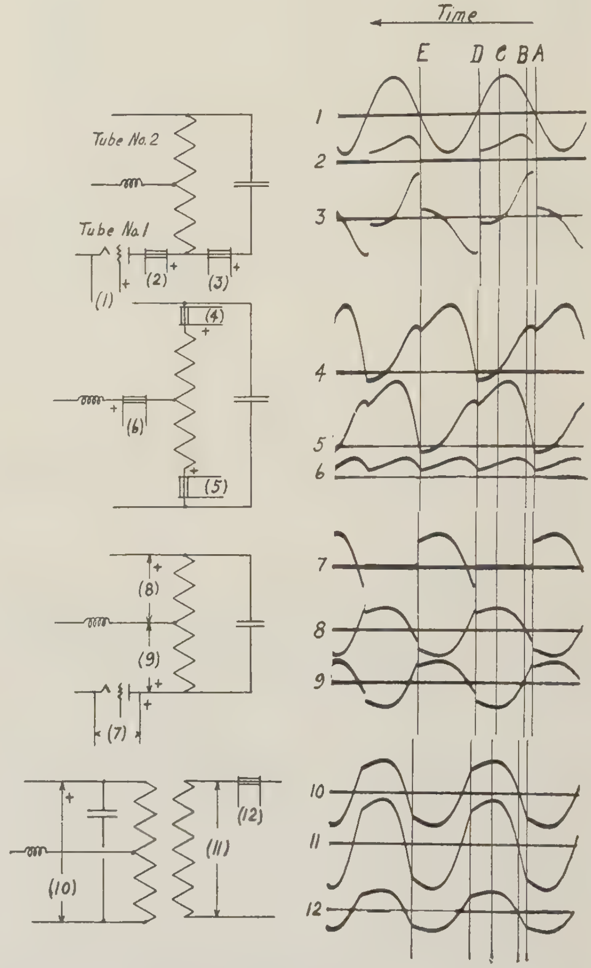


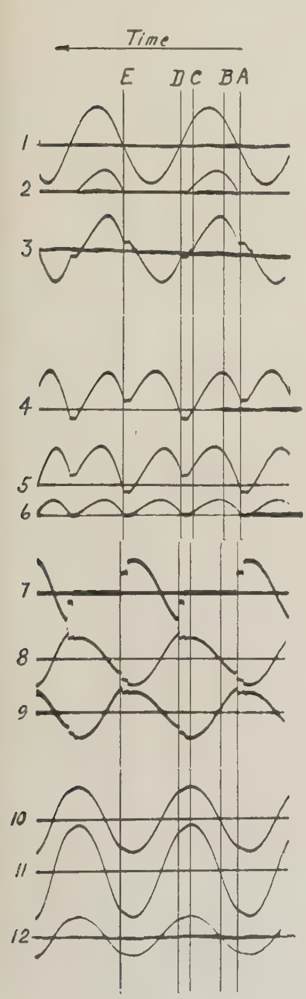
Fig. 2. Oscillographic study of the operation of the parallel type of inverter

Output 18 amp, 110 volts; diagrams at left show positions of oscillograph elements

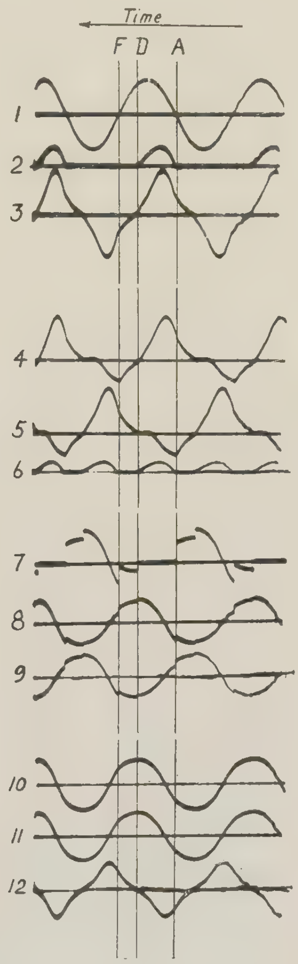
Time *C* is interesting for at this time the flow of current into the condenser has stopped as indicated by curve 3, and consequently the current through one half of the primary winding also has stopped as shown in curve 4. From curves 8, 9, 10, 11, and 12 it may be noted that at this time the transformer

voltages and output current are at nearly their maximum values.

From C to D the flow of current in the condenser reverses, since the potential of the transformer primary winding is falling thus leaving the condenser at a higher voltage. The reversal of current in the condenser is shown in curve 3 and the consequent reversal of current through one-half of the transformer primary winding in curve 4. This reversed current continues until the other tube starts conducting.



Output 5 amp, 110 volts, non-inductive



Output 19 amp, 110 volts, 11.5 per cent power factor; capacitor $6^3/_4$ μf, inductance 0.20 h (See Fig. 1)

Fig. 3. (Left) Oscillographic study of inverter operating at light load

Fig. 4. (Right) Same with inductive load

Time D illustrates the stopping of conduction in tube No. 1 and the starting of conduction in No. 2. Curve 1 shows that when the grid voltage of tube 2 becomes zero, current starts to pass through this tube, the flow through tube 1 stops as indicated by curve 2 and the condenser charges in the reverse direction as shown by curve 3. Curve 7 indicates the negative potential that appears between the anode and cathode of tube 1 which permits deionization to take place. The time that this anode remains negative is given by the distance between the sudden negative drop to the point where the curve again crosses the zero line in the positive direction. This time, while short, is long enough for the gas content of the tube to become deionized; this requires only approximately 100 μsec for the tubes used in these experiments. From the time conduction starts in the other tube, conditions in the circuit are similar to those already described, tube 2 replacing tube 1 and the other half of the transformer primary winding carrying the tube current. It may be seen that only half of the primary winding is active at a given time as far as output is concerned. This fact must be taken into account when choosing the transformer ratio desired for an inverter circuit.

Commutation

The method of stopping the operation of one tube when the other starts, under the conditions shown in Fig. 2, may be analyzed as follows: Just an instant before time D, tube 1 is conducting as shown by curve 2; the voltage of its half of the primary winding is shown by curve 9. At time D the grid voltage of tube 2 becomes zero; this allows the tube to start carrying current, the anode potential being positive as is seen in curve 8. When this occurs the full potential of the primary winding less the voltage drop in tube 2 is impressed on tube 1, the cathodes being connected together completing the circuit. This action causes the cathode of tube 1 to become for a time more positive than its anode, thus stopping the current flow; the voltage impressed on this tube is shown in curve 10. The anode remains negative to the cathode for a sufficient length of time for deionization to take place, and when it does become positive the grid potential is sufficiently negative to prevent the current from starting. From this analysis it follows that the action of the condenser is to give the correct phase relations for commutating action.

Oscillograms for light-load operation are shown in Fig. 3. It may be seen that in many cases the shapes of the curves are greatly altered, and that the output wave form is better. An analysis of the operation in this and in succeeding sets of oscillograms does not differ materially from that just made.

Low Power Factor Loads

The parallel type of inverter will carry low power factor loads when the circuit has the proper constants. An example of the operation with lagging current is given in the oscillograms of Fig. 4. The output voltage and current, curves 11 and 12, show that the current was lagging and that the power factor was low. In this as in the preceding example, current through one tube stops some time before that through the other starts. This operation is characterized by the 2 distinct negative voltage drops appearing between the cathode and anode of the stopped tube as shown by curve 7.

Operation with a low power factor leading current load is shown in the oscillograms of Fig. 5. It is interesting to note that the condenser is not needed in this case, as is indicated by curve 3, the necessary phase relation between the input current and the induced primary voltage being caused by the load.

Output wave forms differ with the amount and power factor of the load when fixed values of capacitance and inductance are used in the inverter circuit. With unity power factor, the best wave form is given at light load; but as this is not as interesting a condition as full load, it was the wave form of the latter which was analyzed. When the curves for this analysis were obtained the output voltage was not held at 110 volts as was done previously. Results of the analysis are as follows:

Effective voltage	122 volts
Average voltage	115 volts
Form factor	1.06
Peak factor	1.30
Maximum value of the 3d harmonic	16.75 volts
Maximum value of the 5th harmonic	6.35 volts
Maximum value of the 7th harmonic	2.80 volts
Maximum value of the 9th harmonic	1.18 volts

Regulation and Efficiency

The amount of capacitance used in the circuit has great bearing upon the voltage regulation of this type of inverter. It also has a large effect on the output wave form so that a reasonable compromise must be made. Low capacitance gives the best voltage regulation and the poorest wave form and may cause instability; too much capacitance reduces the output voltage to a considerable extent.

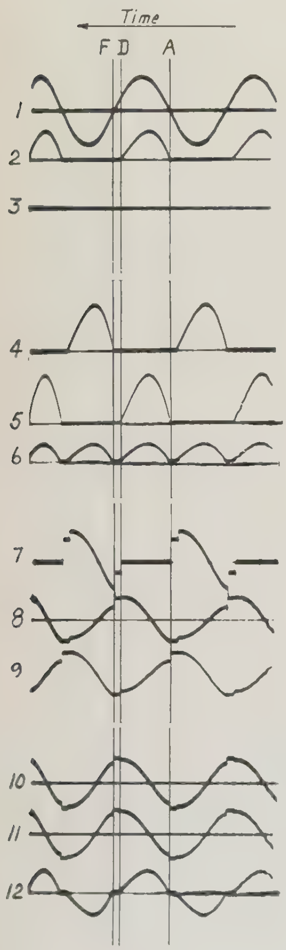


Fig. 5. Oscillographic study of inverter operation with capacitative load

Output 18 amp, 110 volts, 10.1 per cent power factor; no capacitor; inductance 0.20 h (See Fig. 1)

Efficiency of the inverter using gas-filled tubes is high largely because of the high efficiency of the tubes themselves. With an average tube potential drop of only 15 volts and with reasonably high anode voltage, the losses in the tube are small and the efficiency high. Efficiency and voltage regulation curves are given in Fig. 6; as may be seen, the regulation with $4^1/_2$ μf capacitance is much poorer than with $1^1/_8$ μf. However, to secure a reasonably good output wave form it was necessary to use the higher value.

Conclusions

Oscillograms reproduced in this article demonstrate in a graphical way the complete operation of the inverter under widely varying load conditions. The circuit is a most interesting one and already has been applied commercially for supplying power to a-c radio sets where operation from d-c systems is required.

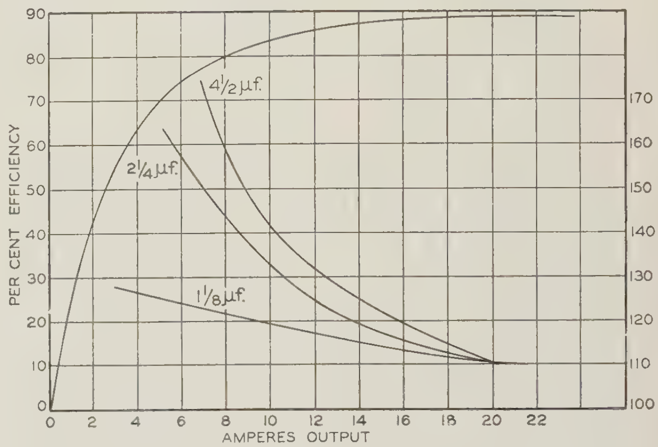


Fig. 6. (Right) Efficiency and voltage regulation curves of the inverter

The steel tank mercury arc rectifier, when equipped with grids, operates in the same manner as the grid-controlled gas-filled tube and thus can be used in inverter circuits. When large amounts of power are required, this device rather than glass walled tubes will be used. Inversion up to 4,500 kw has been secured this way in the laboratory (see "Grid-Controlled Mercury Arc Rectifiers," by H. D. Brown, *G. E. Rev.*, v. 35, Aug. 1932).

Nothing has been said about parallel operation of inverters with systems supplied by synchronous machines. This is a perfectly feasible method of operation and has the advantage that no capacitor is required in the inverter circuit, thus making the operation more stable. No data indicate that the difficulties of operation of the inverter are insurmountable; since the growth of electrical engineering seems to be in the direction of an increasing use of thermionic devices, it may well be expected that circuits of this nature rapidly will become of importance. [Those seeking further information on the inverter are referred to a list of 16 references which was included in the author's original paper and which was published on p. 713–14 of the September 1932 issue of the A.I.E.E. Transactions.]

Engineers and Progress

Periodically mankind has bewailed the end of substantial progress, repeatedly to find that the apparent end was in fact a beginning. Quotations from the published works of previous eras are given in substantiation of the maintenance of a constructive, forward-looking attitude in spite of present awesome difficulties.

By
BANCROFT GHERARDI
PAST-PRESIDENT A.I.E.E.
Am. Tel. and Tel. Co., New York, N. Y.

After reading some of the history of the social and economic world during the last two or three hundred years, it is curious to note how much surprise there is at the present time in regard to this depression. It is, generally speaking, regarded as something quite novel, quite unprecedented, and it is seriously questioned by many whether we will come out of it. We seem to think of depressions as people in the earlier times thought of a total eclipse of the sun. It was new to them and they were terrified by it, and they did not know whether it would ever end, or how. Today we are not terrified by eclipses.

In an article published in 1830, more than 100 year ago, Macaulay, the British essayist, in the Edinburgh Review said:

> The present moment is one of great distress. But how small will that distress appear when we think over the history of the last forty years;—a war, compared with which, all other wars sink into insignificance;—taxation, such as the most heavily taxed people of former times could not have conceived;—a debt larger than all the public debts that ever existed in the world added together. . . .
>
> If we were to prophesy that in the year 1930, a population of fifty millions, better fed, clad, and lodged than the English of our time, will cover these islands . . . —that machines, constructed on principles, yet undiscovered, will be in every house,—that there will be no highways but railroads, no travelling but by steam,—that our debt, vast as it seems to us, will appear to our great-grandchildren a trifling encumbrance, which might easily be paid off in a year or two,—many people would think us insane. . . .
>
> Hence it is, that though, in every age, everybody knows that up to his own time progressive improvement has been taking place, nobody seems to reckon on any improvement during the next generation.
>
> We cannot absolutely prove that those are in error who tell us that society has reached the turning point—that we have seen our best days. But so said all who came before us, and with just as much apparent reason. . . .

This article by Macaulay was written in 1830 and not in 1930.

Turning to something which was said in our own country in New Haven, Connecticut, in 1837, 95 years ago.

> A few months ago, the unparalleled prosperity of our country was the theme of universal gratulation. Such a development of resources, so rapid an augmentation of individual and public wealth, so great a manifestation of the spirit of enterprise, so strong and seemingly rational a confidence in the prospect of unlimited success, were never known before. But how suddenly has all this prosperity been arrested! That confidence, which in modern times, and especially in our own country, is the basis of commercial intercourse, is failing in every quarter; and all the financial interests of the country seem to be convulsed and disorganized. The merchant, whose business is spread out over a wide extent of territory, and who, regarding all his transactions as conducted on safe principles, feared no embarrassment, finds his paper evidences of debt, and acceptances and promises which he has received in exchange for his goods, losing their value; and his ability to meet his engagements is at an end . . . and loss succeeds to loss, till he shuts up his manufactory and dismisses his laborers. The speculator who dreamed himself rich, finds his fancied riches disappearing like an exhalation. . . .
>
> Already, in many a huge fabric that but a few days since resounded with the roar of enginery, all is silent as in a deserted city. . . . Already want, like an armed man, stands at the threshold of many a dwelling, where a few days ago, daily industry brought the supply of daily conforts. . . .
>
> Amid these present calamities, and these portentous omens of the future, it is not strange that many minds are seeking, and all voices are debating, the cause and the remedy.

Note the reference nearly 100 years ago to the speculator who dreamed himself rich and finds his fancied riches have disappeared.

Let us now step ahead a little in time and consider an extract from an editorial which was published in *Harpers' Weekly* in 1857, about 75 years ago.

> It is a gloomy moment in history. Not for many years—not in the lifetime of most men who read this paper—has there been so much grave and deep apprehension; never the future has seemed so incalculable as at this time. In our country there is universal commercial prostration and panic, and thousands of our poorest fellow-citizens are turned out against the approaching Winter without employment, and without the prospect of it.
>
> In France the political cauldron seethes and bubbles with uncertainty; Russia hangs as usual, like a cloud, dark and silent upon the horizon of Europe; while all the energies and influences of the British Empire are sorely tried, and are yet to be tried more sorely.
>
> It is a solemn moment, and no man can feel an indifference in the issue of events.
>
> Of our own troubles no man can see the end. . . .

Note the gloom and note the reference to the European situation.

Now moving forward to 1886, let us consider a brief abstract from the First Annual Report of the U.S. Commissioner of Labor, Carroll D. Wright, written and published 47 years ago.

> The rapid development and adaptation of machinery in all the activities belonging to production and transportation have brought what is commonly called over-production, so that machinery and over-production are two causes so closely allied that it is quite difficult to discuss the one without taking the other into consideration. . . . . On all sides one sees the accomplished results of the labor of half a century. From a financial point of view, these accomplished results should always be good, but in many cases it is apparent that undertakings have proved deceptive and Governments become needy and some . . . insolvent. Whatever may have been the financial results, industry has been enormously developed, cities have been transformed, distances covered, and a new set of economic tools has been given in profusion to rich countries, and in a more reasonable amount to poorer ones. What is strictly necessary has been done oftentimes to superfluity. This full supply of economic tools to meet the wants of nearly all branches of commerce and industry is the most important factor in the present industrial depression. It is true that the discovery of new processes of manufacture will undoubtedly continue, and this will act as an ameliorating influence, but it will not leave room for a marked extension, such as has been witnessed during the last fifty years, or afford a remunerative employment of the vast amount of capital which has been created during that period. The market price of products will continue low, no matter what the cost of production may be. The day of large profits is probably past. There may be room for

The substance of an address given January 11, 1933, at the annual dinner of the Society of Automotive Engineers, New York, N. Y., and subsequently published in the Bell Telephone Quarterly for January 1933.

further intensive, but not extensive, development of industry in the present area of civilization.

Note the suggestion of technological unemployment and note that the day of large profits is probably past, or so he says.

Any one of these quotations could be read almost without the change of a word to describe the present situation, and these are only a few of the quotations that are available. Any number can be gotten together of the same general type.

It is particularly interesting, to engineers, in connection with this depression, that, while Wright in his report of 1886 hints more or less at the responsibility of the scientist, the engineer, the chemist and others for the depression, that is, for the creating of technological unemployment, the current depression is really the first for which scientists and engineers have been generally blamed. Not only have scientists and engineers had to stand their share of the grief of the depression, but, adding insult to injury, they and others who are applying science to the uses of mankind are blamed for the depression.

It is clear that the scientist, the engineer, and the others applying science to the uses of mankind have done much for the world. They have freed the world from the physical menace of famine. They have raised the general standards of living. They have supplied mankind with increased leisure. They have provided new means and opportunities for education, entertainment, and amusement. They have relieved man of much of the drudgery of labor. These have been great achievements but progress has not ended. There are going to be new industries, the nature of which is not conceived of at the present time any more than Wright could see clearly ahead in 1886 when he practically said that about everything that was worth while doing had been done and that there was not much more to do.

At that time the telephone was 10 years old and had but little commercial development. He never thought that it would develop to the point where it would furnish employment to about one per cent of the total working population of the United States. The automobile, of course, was not in the picture at all. Electric light and power distribution were scientific toys. The moving picture had not started its career. In fact, any one can think of a hundred and one things which were not available in 1886 and which are important parts of the social and economic life today, and which furnish employment to millions.

If we were to put ourselves on record as saying that 50 years from now there would not be much of anything of importance except those things which we know of today, somebody 50 years from now might quote such a statement as being an amusing illustration of shortsightedness.

It seems clear from reading past economic history that every severe depression is accompanied by certain assumptions by the people of the time. In the judgment of current observers, each depression is regarded as being more severe than those which came before. It is assumed to be of novel character and to have deep-seated causes which either cannot be removed at all or which can be removed only by revolutionary changes. Such a period of depression always gives rise to all kinds of proposals and suggested cures. Some of these, especially those the least fundamental in character, prove to be worthy of serious consideration and trial. Many, subsequent events show, can be classed only as foolish or fantastic. In the past, notwithstanding that the panaceas which were recommended as being the only cure of the then current depression were not adopted, the depression ended just the same and industry went on to higher levels.

These statements should not be interpreted as belittling the seriousness of the existing situation. It is serious. It is deplorable. All of the things which are being done to help the situation should be continued and perhaps others will be necessary. History, however, indicates that we do not necessarily need fundamental changes. Certain symptoms need treatment. There are evolutionary changes going on all of the time. These should be continued. If other things are thought of which it is clear will be helpful, they should be done. But the past tells us that there is no use in looking around for a Moses to lead us out of our troubles. We don't get out of depressions by the leadership of Moses. There is no use of looking for a grand and comprehensive plan which will fix everything. We all contributed to getting into our present difficulties and we must all contribute to getting out of them. This process has successfully brought us out of previous depressions.

Engineers may, congratulate themselves on the contributions that they have made to civilization. The problems of this era are not the problems of the past. Economic history tells us that up to a period of, say, one hundred years ago, the problems of the world were problems of want as well as the problems of distribution. The methods of production did not permit of creating enough to enable more than a very small number of the inhabitants of the world to live on any basis above a bare level of sustenance. Our problem today is only a part of the former problem and should be a simpler one. It is not the problem that we haven't got and can't get the things necessary to give us a higher economic level. It is the problem of the distribution of plenty. The problem that must be solved now is not the problem of how to create enough to keep the bulk of the people of this country above the level of want. Our problem is, having the ability to produce it, how to distribute it to the population. This change in the social problem is the major contribution to the world of the scientist and those who have worked on the application of science, the engineer, and others.

The words which Macaulay wrote in 1830 seem to apply to the situation now as they did when written:

> We cannot absolutely prove that those are in error who tell us that society has reached the turning point—that we have seen our best days—but so said all who came before us and with just as much apparent reason.

The future holds in store for engineers opportunities at least as great as, if not greater than, any that they have had in the past.

What Is Reactive Power?

ONE FEATURE of the Institute's North Eastern District meeting to be held in Schenectady, N. Y., May 10–12, 1933, is a symposium on reactive power, held under the chairmanship of A. E. Knowlton. An introduction to this symposium prepared by Mr. Knowlton is presented herewith, following which are the 2 papers of the symposium available and approved in time for publication in this issue. One of these, by J. Allen Johnson, is written from the practical point of view, and the other, by V. G. Smith, is written from the theoretical point of view. Although these 2 papers do not cover all of the many factors involved in the discussion on reactive power, they are representative of different schools of thought.

Among the questions which it is expected will be discussed during this symposium are (1) methods of measuring and defining reactive power accurately, rigidly, theoretically; (2) adoption of a standard convention of either leading or lagging reactive current as positive; and (3) suitable names and symbols for the 3 sides of the triangle composed of in-phase, quadrature, and combined power.

The decisions reached by the International Electrotechnical Commission on July 9, 1930, regarding the definitions and units involved in questions 1 and 3 were presented in ELECTRICAL ENGINEERING for February 1931, p. 142. Question 2 was presented in the February 1932 issue, p. 106, as part of the report of the Institute's subject committee on definitions, "Proposed Definitions of Power System Terms" wherein discussion was requested as to whether leading or lagging reactive current should be considered positive. All 3 of these questions have been discussed in "Letters to the Editor" appearing in ELECTRICAL ENGINEERING during 1932: March, p. 208; August, p. 597–8; October, p. 744–5; and December, p. 888.

In conducting this symposium, the Institute's subcommittee on reactive power hopes that the papers to be presented will serve to clarify many of the concepts of reactive power. Discussions, written or oral, from interested persons are invited.

I—Reactive Power Concepts in Need of Clarification

To assist in clarifying the present concepts of reactive power, the following introduction to the subject has been prepared. An analysis of the reactive conventions made by Doctor Silsbee, a member of the subcommittee, is included.

BY
ARCHER E. KNOWLTON Chairman, A.I.E.E. Subcommittee on Reactive Power
FELLOW A.I.E.E.

IF ALL electrical iron could by divine decree or presidential proclamation be straightened into uniform permeability over its whole range of magnetization there would be less occasion to raise the question of adequacy of our prevailing concepts of reactive power and power factor. If all synchronous machine windings under all conditions of loading could have flux distribution in strict conformity with symmetrical sinusoidal generation there would be still less. Moreover, the excuse would nearly vanish if polyphase circuits could always be held to rigid balance of impedances on their lines and loads. With these factors eliminated the residue of doubt, if any, would be a topic to intrigue only the academic and metaphysical minds.

But no one of these 3 ideals is attained fully in practice and the degree of departure in any particular instance is what justifies an effort to take some of the slack out of the power factor and reactive concepts. However, power factor is only a ratio expressing the interrelations between true power, apparent power, and reactive power. The focus is at once upon reactive power because of the 3 aspects of energy flow, it has been given second place in analysis and measurement.

The quadrature component accompanying energy flow in inductive and capacitive circuits has vagaries which, relatively speaking, have been overlooked while energy, power, voltage, and current were being explored and reduced to systematic and conventional procedure. During the last 5 years there has been a growing disposition in academic circles to turn the mathematical weapons concertedly upon the reactive constituent. To Prof. Constantin D. Busila of the Polytechnic School at Bucharest, Roumania, and Roumanian representative on the International Electrotechnical Commission, is given most of the credit for bringing the loose status of flux-energy to the fore. At the International

This article serves as an introduction to the reactive power symposium which will be presented at the Institute's North Eastern District meeting, Schenectady, N. Y., May 10–12, 1933.

Conference on High-Voltage Electric Systems (Paris, 1927), Professor Busila presented a paper, "The Power Factor and Its Improvement." Discussion of it disclosed such differences of opinion on the basic phenomena that a special advisory committee was formed under Roumanian sponsorship. Out of it came the Roumanian "Questionnaire on the Problem of Reactive Power" which was given international circulation.

No categorical answer to that questionnaire has been given by the A.I.E.E. A special subcommittee* was constituted by the standards committee to prepare an answer. In 1931 the only answer that could even partially be agreed upon as a suggestion to the standards committee for transmission to the Roumanian committee was that:

> " . . . . . prevailing methods of measuring reactive components are acceptable as a practical expediency, although it is recognized that errors of measurement are incurred under unbalanced and non-sinusoidal conditions. However, the relative unimportance, from the economic standpoint, of reactive power flow as compared with demand and energy elements of electricity costs tends to discount the value of an exhaustive and abstract analysis of the inconsistencies of reactive concepts and the corresponding technique of measurement. In brief, American practice is content with the definition of reactive component as that quantity which is measured when the potential is shifted to quadrature with its appropriate vector position for true power measurement."

Such an answer at the most appears to be evasive or temporary and not erudite or graced with much professional courtesy. The committee set about assembling the foundation for a more comprehensive answer. The symposium on reactive power at the Institute's North Eastern District meeting in Schenectady, May 10–12, 1933, is one result and is a major phase of the subcommittee's activity.

That is the history. Now why so much conern about a circuit manifestation that is always subordinate to the energy and power objectives of practical operation? It is condoned and tolerated, manipulated subserviently, by some viewed merely as the source of power-factor characteristics, by others as merely something to be metered as simply as possible. But the Institute owes to the profession the reduction of the quadrature component to the same degree of specificity as has been done with the true power and energy. Otherwise there can be no rigid definition of power factor (we have one now but it is admittedly not the whole and final answer). In fact the whole uncertainty about reactive power could readily be exaggerated to the point where power factor would have to sacrifice its present abode among the élite definitions (like those of energy, potential, capacitance, etc.) and move into a more plebeian neighborhood (among diversity factor, load factor, use factor, etc.). Some of the queries raised about the quadrature component must, unless it is reduced to systematic treatment, lead to that result for all persons who think occasionally of circuits other than those permanently balanced and subjected only to sinusoidal currents and sinusoidal voltages.

Energy in transit in an electrical system can perhaps be likened to an army on the march over varied terrain. The ideal would be an accelerated and synchronized movement of all branches up to noon and a decelerated movement toward nightfall and encampment—smooth progress "all above the line" like the instantaneous progress of energy in a non-reactive circuit. But actually the tired and ponderous units "lag" and delay the procession when the going meets obstacles. Light and eager units "lead" the rush when there are vacant and alluring tarrying points ahead. Most of the army ultimately gets to its destination and is potentially useful on arrival but the route and the terminal bring out the mobility idiosyncrasies of heavy tanks and fast motor units, speedy cavalry, and sluggish infantry. The laws of the mass movement are relatively simple but the laws of the out-of-phase movements are a bit intricate. Inject the rearward movement of units back to the base for refreshment and recoupment and the picture becomes more compete and more intricate. What is the "power factor" of such a system? What would it be for a complete military force embracing 3 armies moving in parallel to a common objective?

To make the presentation more specific in electrotechnical terms here are a few of the vagaries, occasionally stated categorically but in fact subject to argument and, at present, opinion. The author disclaims any intention to take sides on any point. The intent of this introduction and of the Schenectady symposium is to elicit all viewpoints with the hope of clarifying the issue and making progress toward conventional handling of the concepts, the terminology, the symbolism, the metering and the economic application of the reactive component of energy flow. The following are largely paraphrased from the Roumanian Questionnaire.

1. Reactive power is not conserved in exchanges between circuits of different frequency (rotor and stator of induction motor, for example).

2. Reactive power to some may present a paradoxical tendency to change sign when the phase-sequence or alternator rotation is reversed.

3. For some, reactive power is distinct from the mean intrinsic energy localized in the electric and magnetic flux fields.

4. Some apparently attribute to reactive power only that degree of reality that attends the circulation or oscillation of intrinsic energy between the reactive receiving devices and the transmitting network.

5. Since (4) leads to a mean value of zero for the instantaneous condition of the interchanges, some hold that reactive power is wholly fictitious and has no reality.

6. Even though the accepted labelling of reactive power as $V \sin \varphi$ is identical with $2\omega(W_L - W_C)$, that is, twice $2\pi f$ times the net difference between instantaneous magnetic and electrostatic energies, for sinusoidal conditions, what will be taken for f where non-sinusoidal conditions arise from a superposition of frequencies?

7. The preceding items indicate the necessity of establishing the degrees of reality and fictitiousness which shall be assigned to reactive power.

8. Until this is done there remains an element of uncertainty in the following commonplace relationships for all but the ideal transfers of energy in which volts, amperes, and watts hold to strictly sinusoidal behavior:

$$P = EI \cos \varphi$$
$$Q = EI \sin \varphi$$
$$EI = \sqrt{P^2 + Q^2}$$

9. With equal doubt therefore about Q and φ there is a geometrical uncertainty in the vector diagrams which represent the effective values of non-sinusoidal quantities or the single-phase equivalents of unbalanced polyphase quantities. The conventional way of finding the sinusoidal equivalent of non-sinusoidal quantities meets

* Subcommittee on reactive power: Vannevar Bush, A. L. Cook, W. B. Kouwenhoven, F. A. Laws, P. MacGahan, F. V. Magalhaes, E. J. Rutan, F. B. Silsbee, and A. E. Knowlton, *chairman*.

the requirements of true power but introduces inconsistencies with regard to the out-of-phase manifestations.

10. The rising reversion to d-c by way of rectification devices brings non-sinusoidal manifestation to the fore and thus accentuates the need for elevating reactive concepts toward parity with the true-power concepts.

11. Substitution of equivalent sinusoids suffices for power treatment but, since the proportioning of the harmonics affects the reactive quantity, the equivalent sinusoids are not wholly determinative for the reactive quantity.

12. Reciprocal deformation effects between current and voltage occasion cross-product terms in the expansion of a power expression which cancel in the final summation for delivered power but they do not cancel correspondingly in the reactive expression.

13. It appears that a deformation factor may be needed to rid the reactive component of its uncertainty under non-sinusoidal conditions or else a term for "deformation power" introduced as a correction. One suggestion (Liénard) has been that "apparent power is equal to the maximum of the values which the active power can take when we modify in all possible manners the form of the current and that of the applied voltage, the effective values of these voltages and currents remaining fixed."

14. In some quarters "reactive factor" (reactive power divided by real power) is coming into use and approaching sanction. It will inherit the same weakness as power factor.

Those are the elements of the problem. The incidence of these areas of doubtful status upon the electric system seems to fall primarily into certain categories. First, there is the mathematical approach to ascertain the degree of reality to be assigned to the quadrature component. This is treated from the abstract point of view by Professor W. V. Lyon in his paper, "Reactive Power and Power-Factor." Second, there is the analysis of the non-conservative attribute of reactive power when viewed from the standpoint of the mesh which constitutes the practical system of power transmission; Professor V. G. Smith's paper, "Reactive and Fictitious Power," is on this topic. Third, the technique of symmetrical coordinates could well be applied to this subject to ascertain how much conversion to balanced systems would be helpful in reducing the uncertainties; this C. L. Fortescue has done in his paper, "Power, Reactive Volt-Amperes, Power-Factor." Fourth, power system operators have come to look upon the reactive component as a quantity to be dispatched more or less independently of the true power. About it has grown a technique which should be correlated with the academic analysis; one practice in this respect is presented by J. A. Johnson in his paper, "Operating Aspects of Reactive Power." Fifth, the meter technician has a point of view on this matter because in the final analysis it is his task to meter reactive component in conformity with the standards and conventions. W. H. Pratt expresses this point of view in his paper, "Notes on the Measurement of Reactive Volt-Amperes."

More or less distinct from the foregoing is a call to establish a conventional procedure in representing the reactive component in power triangles. Practice is about evenly divided. Some engineers and writers habitually or advisedly draw lagging reactive component vertically upward and some draw it downward from the right-hand end of the kilowatt base. A leading component is of course given the reverse direction by the 2 schools of thought and practice. Misinterpretation is manifestly possible under such divergent practice where the author asssumes that the reader belongs to his own camp and therefore fails to label his diagrams specifically.

This confusion was referred to the subcommittee by the standards committee so that the United States national committee of the International Electrotechnical Commission may be enabled to recommend through Prof. A. E. Kennelly to the committee on electromagnetic and magnetic units, the conventional treatment preferred by the A.I.E.E. A ballot mailed to 75 actively interested members of the Institute brought response from 50 but there was not a strong preponderance for either standard. The most comprehensive reply was submitted by Dr. F. B. Silsbee, a member of the subcommittee. He advocates standardizing inductive kilovars as

Table I—Alternative Conventions

	I*				II*			
	12. $B = +\frac{X}{Z^2}$ Thus satisfying 4 Whence 13. $Y = G - jB$ violating 2; or stating that Y is *not* the resultant of G and B. The phase angle of admittance is 14. $\theta_Y = \tan^{-1}\frac{(-B)}{G} = -\theta_Z$				$B = -\frac{X}{Z^2}$ violating 4 Whence 13. $Y = G + jB$ thus satisfying 2 The phase angle of admittance is 14. $\theta_Y = \tan^{-1}\frac{+B}{G} = -\theta_Z$			
	IA		IB		IIA		IIB	
15.	$Q = -I^2X$		$Q = +I^2X$		$Q = -I^2X$		$Q = +I^2X$	
16.	$= -E^2B$		$= +E^2B$		$= +E^2B$		$= -E^2B$	
17.	$= +EI \sin\theta_Y$		$= +EI \sin\theta_Z$		$= +EI \sin\theta_Y$		$= +EI \sin\theta_Z$	
	IAa	IAb	IBa	IBb	IIAa	IIAb	IIBa	IIBb
18.	$V = P + jQ$	$V = P - jQ$	$V = P + jQ$	$V = P - jQ$	$V = P - jQ$	$V = P - jQ$	$V = P + jQ$	$V = P - jQ$
	For a circuit in which inductance predominates Q will be drawn							
19.	down	up	up	down	down	up	up	down

* For either of these conventions, the reactive volt-amperes Q may conceivably be defined as either + or −, thus giving 4 alternatives, and (if a further violation of principle 2 is invoked) each of these 4 alternatives gives rise to 2 ways of drawing the power triangle; i. e., as $V = P + jQ$ or as $V = P - jQ$. The resulting 8 procedures are here shown in tabular form.

positive and capacitive kilovars as negative in power triangles.

With no intention of influencing any one who may wish to contribute his preference for the committee's guidance but merely because it displays admirably the factors upon which a decision could be based on analytical grounds as contrasted with the habitual, the presentation of Dr. Silsbee is incorporated herewith. The committee will welcome letters from Institute members who read this and, because of it or in spite of it, hope to see a particular geometrical direction assigned to reactive power of the inductive and capacitive forms when represented with power and volt-amperes in power triangles. Dr. Silsbee's presentation follows:

Alternative Processes for Defining the Sign of Reactive Volt-Amperes

The following general principles may be set up as governing the adoption of scientific conventions as to the signs of electrical quantities:

1. Positive real quantities are drawn to the right, and positive imaginary quantities are drawn upward.
2. A resultant effect is the (complex) sum of its components. Thus if c is the resultant of a and jb, we write $c = a + jb$ and draw b upward.
3. By the rules of complex algebra d, the reciprocal of c is given by

$$d = \frac{1}{c} = \frac{1}{a + jb} = \frac{a}{a^2 + b^2} - \frac{jb}{a^2 + b^2}$$

4. The unnecessary introduction of negatives in fundamental definitions is to be avoided.

Of the foregoing statements, 1, 2, and 3 are part of our fundamental mathematical notation and are now so universally accepted as to stand unchallenged. Statement 4 is a more philosophical point but of generally recognized weight.

Confining our attention to sinusoidal current I and voltage E we have

5. $R = P/I^2$, P being the real power.
6. $X = \omega L - \dfrac{1}{\omega c}$
7. $Z = R + jX$.
8. The phase angle of the impedance is $\theta_z = \tan^{-1} \dfrac{X}{R}$.

The sign of X is the result of a purely arbitrary choice, made so long ago that there seems little need, or hope, of changing it. Eq 7 indicates that impedance is the resultant of resistance and reactance in the sense of principle 2.

We also have the definition

9. $Y = \dfrac{1}{Z}$

which by principle 3 leads to

10. $Y = \dfrac{R}{Z^2} - \dfrac{jX}{Z^2}$

and as an abbreviation we define the conductance

11. $G = \dfrac{R}{Z^2}$

All of the relations to this point follow from the arbitrary principle 6, with no violation of any of the first 4 principles. In the definitions of susceptance, B, however, 2 alternatives present themselves. One of these, which is that generally used (certainly in the United States) will be designated in Table I as **I**; while the opposite, which will be designated by **II**, has been urged by some. The inherent difficulty from the minus sign in 3 is met in a different fashion in the 2 conventions and neither is all that could be desired.

Of the alternatives in Table I it will be seen that **IBa** is the only one which does not involve at least one violation of principle 2 or 4 in addition to the unavoidable violation at step 12 or 13 which occurs in all procedures. Alternatives **IIA** and **IIB** both suffer from the inconvenient change in form (though not in substance) according as Q is defined from X or from B.

The drawing of the power vector parallel to the current vector (down in the inductive case) is attained in **IAa, IBb, IIAa** and **IIAb.**

In addition to the formal principles listed above consideration should also be given to the following facts:

20. The almost universal use of constant voltage systems for the transmission and utilization of electric power makes the calculation of circuits by using their admittance, conductance, and susceptance the most logical and direct.
21. Habits of thought arising by the historical accident that series circuits were first studied theoretically make the average engineer more familiar with the quantities impedance, resistance, and reactance.
22. The use of reactive power as equivalent to $2\omega(W_m - W_e)$ where W_m and W_e are the magnetic and electrostatic energies, has already come into considerable use in the literature.

II—Operating Aspects of Reactive Power

"Reactive power" is discussed in this article from the point of view of the practical operating engineer. The direction of flow in a transmission line of this reactive power with respect to the "active" power is shown to determine whether the current lags or leads the voltage. It is urged that only one kind of reactive power (lagging) be recognized, and that its direction of flow be considered. A simplification of system operating problems is claimed to result from this view. Use of the symbol *rkw* is urged.

By
J. ALLEN JOHNSON
FELLOW A.I.E.E.
Buffalo, Niagara and Eastern Power Corp., Buffalo, N. Y.

THE SUBJECT of the symposium of which this is a part is "reactive power." This term is somewhat unfamiliar to many engineers, and some might even strongly deny the existence of reactive "power." The conception of reactive current as "wattless" is so deeply ingrained that the term "reactive power" will doubtless meet with reluctant acceptance. In one sense this conception of "wattlessness" is true, but in another, and apparently equally valid sense, it seems not to be true. It is therefore proposed to accept the title at its face value, and present the point of view of an engineer in the operating field, in which reactive

Full text of a paper "Operating Aspects of Reactive Power" (No. 33-56) to be presented at the Institute's North Eastern District meeting, Schenectady, N. Y., May 10–12, 1933.

power is conceived of as a kind of power different and distinct from power in its ordinary meaning (which hereinafter will be called "active" power) but with which the operator nevertheless has to deal in much the same manner.

It happens that this kind of reactive power is the kind which causes the current to lag behind the voltage when it happens to be flowing in the same direction in the circuit as the active power. However, when it happens to be flowing in the direction opposite to that of the active power (which, in a transmission system is just about as likely to happen) it makes the total current in the circuit appear to lead the voltage and deceives the technician who observes this phenomenon into thinking that a different kind of reactive power (*viz.*, leading reactive power) is flowing in the same direction as the active power. An interpretation of such observations is here presented in terms of the one kind of reactive power with which the practical operation and control of power systems has to deal, and the parallelism between active and reactive power in their operating aspects is pointed out. There is also presented an unorthodox metering technique for keeping track of the flow of reactive power in a complicated power transmission network, that greatly clarifies and simplifies the problem of dispatching reactive power in such a system; such dispatching being necessary to obtain maximum transmission system capacity and efficiency as well as for system voltage control.

Two Views of Reactive Power

There are 2 points of view from which the subject of reactive power may be regarded. The first of these may be called the academic, mathematical, or technical point of view, and the second the practical, engineering, or operating point of view. Let us first clearly distinguish between these 2 points of view which we will call briefly the "academic" and the "practical."

Characteristics of Academic View

The academic point of view results from consideration of what is going on at a certain point in a circuit. Instruments are inserted and measurements made of current, potential, and power. From these it is often found that the measured watts are less than the product of the measured amperes and the measured volts by a certain factor, which we call the "power factor." From these relationships and familiar known laws, we can determine the in-phase and quadrature components of the flow (and their phase relationship) which in this view we think of as inseparable and more or less imaginary components of the "total kilovolt-amperes" in the circuit. While this technique does inform us fairly well as to what is occurring at the point of measurement, it does not lend itself at all well to the visualization of what is happening in the system as a whole nor to a practical technique of system control. It does not give us the picture of 2 independent things going on in the circuit at the same time.

In representing these quantities and relationships on paper the technician uses a device which he calls a "vector diagram." In such diagrams, counterclockwise vector rotation is usually considered standard, and right hand and upward vectors, positive. The "academic" viewpoint seems to have its origin in these conventions, as does also the question as to the "sign" of reactive power.

Characteristics of Practical View

The "practical" point of view results from a consideration of what is going on, not at one point in a circuit but throughout the entire electrical power system. The operating engineer is faced with the problem of controlling the operation of his system and hence is interested in tracing the 2 kinds of power flow found at any one point back, on the one hand, to their sources and forward, on the other hand, to their destinations, in order to discover how he can control their sources in and courses through the system. What does he find?

He finds that the active power (neglecting losses for the moment) originates in a prime mover, passes thence through a mechanical connection of some sort into a "generator" where it is converted into electrical power. After traversing the system this power arrives (let us say) at induction motors where it is converted back to mechanical power and passes on to the driven machines. Or it may be converted directly into heat and leave the electrical system in that form. In any case it flows, like a stream, into the electrical system at one end and out at the other.

He finds that the demand for reactive power originates for the most part in the excitation requirements of induction motors and other devices using iron magnetic circuits which draw their excitation, in the form of lagging reactive current, from the same circuits through which the active power is flowing. Following this reactive power back through the system he finds that it has its origin in the field circuits of the generators. He knows this must be so because he finds he can control the amount of reactive power supplied by any particular generator by varying its field current. This reactive power therefore apparently originates within the electromagnetic system and never leaves it, but reacts back and forth between the generators and the motors. Hence its name "reactive power" and its logical symbol *rkw* used hereinafter. [Editor's Note: The author's symbol *rkw* (and the corresponding term *reactive kilowatt*) is used advisedly in this article, rather than the standard editorial style *rkva*, or the symbol *kvar* adopted by the International Electrotechnical Commission, July 9, 1930.]

He further finds that the flow of the active power through his system produces comparatively little drop in potential, whereas the flow of reactive power is much more serious in this respect; also that if the reactive power is generated in the same generators through which active power is supplied, and flows through the same circuits, it requires increased current capacity of generators, transformers, and lines increases I^2R losses in all current carrying parts of

the system, and limits the active power capacity of the transmission circuits. He finds, however, that active and reactive power do not add together in these circuits algebraically but geometrically in quadrature.

Since reactive power originates in generators and not in prime movers, the generation of reactive power is not subject to the same limitations as to geographical location as is that of active power, but can be generated anywhere desired. Therefore, in order to minimize its undesirable effects on the major parts of the system, reactive power generators (commonly called synchronous condensers) are frequently installed at receiving or distributing substations near the load where the reactive power is required. In many cases generators used to supply active power during one set of conditions may be used to supply reactive power during other conditions.

Since the active and reactive power do not add algebraically but combine in quadrature relation it is obviously more economical, other things being equal, to generate both in the same machine. Where both can be generated near the point of use, this usually proves to be the case, but where the active power must be transmitted long distances, it often proves more economical to generate the reactive power in separate machines near the load, even at the expense of increased total machine capacity. This practice also provides a means of regulating voltage at the receiving end of the lines.

As the 2 kinds of power—active and reactive—flow through the system, losses of both kinds occur due to the resistance, reactance, and capacitance of the circuits. The losses of active power, due to the resistance, are all positive with respect to the active power transmitted and result in less active power being received at the load than left the prime movers. The losses of reactive power, however, with respect to the reactive power transmitted, may be either positive or negative or both, positive losses being due to reactance and negative losses to condensance. It follows that the amount of reactive power delivered to the load may be either more or less than the amount generated.

Let us now inquire what are the conditions and problems confronting the power system operator in controlling his system. Briefly they are as follows:

1. A demand for active power by the customers of the system, and over which he has little or no control.

2. Sources of supply of active power in the form of steam and hydroelectric generating units, perhaps widely scattered, and over which he has control.

3. A demand for reactive power, principally for exciting the motors of the customers, and over which he has little or no control.

4. Various possible sources of reactive power including all of the synchronous generators, condensers, and motors on the system, and over most of which he has control.

5. The demands must be supplied from the various available sources in the most economical manner possible at all times.

6. Voltage must be maintained within certain limits at all stations on the system.

Various other conditions must usually be met but these are the ones with which reactive power is mostly concerned.

In order to operate his system efficiently, and properly control its voltage, the power system operator or load dispatcher must be able to control not only the sources, magnitudes, and directions of the active power flow but also the sources, magnitudes, and directions of the reactive power flow. The magnitude and direction of the active power flow are in practice controlled by adjusting the input to the proper prime movers. The magnitude and direction of the reactive power flow are similarly controlled by adjusting the field currents of the proper generators. To increase the amount of active power supplied by a prime mover the operator increases its power input by increasing its gate or throttle opening. Similarly, to increase the reactive power supplied by a generator or synchronous condenser operating in parallel with other synchronous machines, he increases its field excitation by adjusting its exciter or field rheostat. The 2 processes are analogous and parallel, but independent of each other.

Measuring Instruments

The above are the processes by which the independent control of active and reactive power are effected. To know how to apply these controls, however, it is necessary to measure the magnitudes of the active and reactive power and for this purpose suitable instruments are necessary. The old technique of using wattmeters and power-factor meters was based upon the "academic" viewpoint, in which the total flow in the circuit was treated as a unit. The "practical" viewpoint calls for separate instruments to read the active power and the reactive power. Standard wattmeters will serve both purposes when suitably connected to the circuit. In circuits in which active power can flow in only one direction, left-hand zero instruments can be used for the active power. Where active power may flow in either direction, however, center zero instruments are commonly used. Since reactive power can flow in either direction in practically all circuits, center zero instruments are desirable to measure reactive power in practically all cases.

In the "academic" view, the sense or direction of the reactive power is defined by reference to that of the active power by saying that it "leads" or "lags" according as the current vector leads or lags the potential vector. In a circuit in which active power can flow in only one direction, such as a generator or a radial distribution circuit, this convention leads to little or no confusion. This, however, is not the case in a complicated power network, with widely distributed sources of active and reactive power, and with widely distributed loads, wherein almost any circuit may be called upon to transmit active and reactive power independently in either direction. In such a system, the sources and destinations of reactive power are visualized in the mind of the operator just as definitely as are the sources and destinations of the active power, and it consequently becomes much more natural and logical for him to relate the sense or direction of flow of the reactive power to the circuit in which it is flowing just as he does in the case of the active power rather

than to relate it vectorially to the flow of the active power as in the conventional "academic" point of view. Thus, in this "practical" point of view the flows of active and of reactive power become entirely divorced from each other, the direction of flow of each being independently related to the circuit instead of one to the other.

The conventional system of marking power factor and reactive power meters in terms of "lead" and "lag" thus, in a large power system, introduces difficulties in properly reading and interpreting the readings of these instruments. In a 2-way circuit, owing to the reversible flow of active power, the interpretation of the readings is very confusing as it is impossible to tell, from the readings of the instruments marked in this way, the direction of the reactive power flow unless one knows how the instruments are connected.

Accepting the "practical" convention that reactive power flow is to be defined independently of the active power flow and in relation to the circuits in the same way as the active power flow is defined, it becomes necessary to adopt a convention as to the kind of reactive power that we will talk about. It immediately appears that with this method of treatment it is no longer necessary to discuss both leading and lagging reactive power, since leading reactive power flowing in one direction in the circuit is identical with lagging reactive power flowing in the other direction. Since, as above noted, in a normal electric power system the demand for lagging reactive power predominates over that for leading reactive power and furthermore since the demand for lagging reactive power has its origin in machines with the characteristics of which the operators are familiar and its source is in other machines with the characteristics of which the operators are also familiar, and over which they have control; whereas a demand for leading reactive power is of much rarer occurrence and less familiar to operating men, it follows that *the requirements of operation will be best served if all reactive power flow is treated*

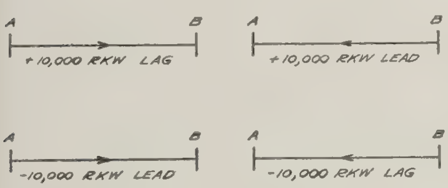


Fig. 1. Four ways of defining the flow of reactive power in a circuit

as lagging reactive power flowing in a certain direction in the circuit.

This is not difficult to do and when it is done consistently it results in the removal of a number of difficulties in handling reactive power flow on a power system. If, in the circuit AB of Fig. 1 there are 10,000 *rkw* lagging flowing from A to B, we can represent the same condition by saying there are $-10{,}000$ *rkw* lagging flowing from B to A, or there are 10,000 *rkw* leading flowing from B to A, or there are $-10{,}000$ *rkw* leading flowing from A to B. So, a leading *reactive kilowatt* in a circuit can always be represented by a lagging *reactive kilowatt* in the opposite direction; and vice versa, a lagging *reactive kilowatt* can always be represented by a leading *reactive kilowatt* in the opposite direction. Therefore, if we should decide to deal with only one kind of reactive power and further decide that that one kind shall be "lagging," any *reactive kilowatt* which formerly was called "leading" will now be called "lagging," with the direction of flow reversed.

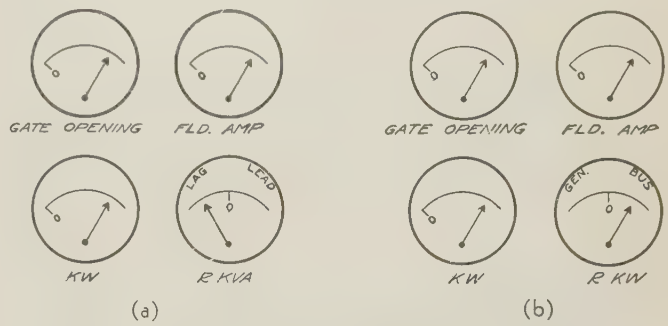


Fig. 2. Academic (a) and practical (b) methods of metering the output of a generating unit

In the academic (conventional) method the field ammeter and reactive power meter pointers move in opposite directions when adjustments of field current are made. In the practical method this inconsistency is eliminated by reversing the connection of the "reactive kilowatt" meter

In Fig. 1 are shown the 4 different ways of representing exactly the same condition.

Conventions for Operation

With the foregoing in mind, and with the aim to obtain a system which is simple and easy to understand and remember, the following conventions might be adopted by an operating power system.

1. Reactive power will always be represented in terms of lagging reactive power and will be designated by the symbol *rkw*.

2. On station log sheets and similar records all readings will be given as a flow between 2 points. The names of these 2 points will be written down in their proper order and connected by a dash or hyphen, such as: "Gen. No. 1–12-kv Bus" or "Lockport-Mortimer." (In this system, transmission circuits are designated by the names of the terminal bus points.) The magnitudes of the kilowatt and *reactive kilowatt* readings will then be recorded and an arrow written just before (or after) each quantity. These arrows will point in the direction of flow as referred to the corresponding points. For example, since "Lockport" is written to the left of "Mortimer" on the log sheet, if power flow is actually from Mortimer to Lockport, the arrow preceding the kilowatt figure will point to the left on the log sheet. Similarly, if reactive power flow is actually from Lockport to Mortimer, the arrow preceding the *reactive kilowatt* figure will point to the right on the log sheet.

3. In marking values of kilowatt and *reactive kilowatt* flow on diagrams, as a matter of convenience, only one arrow need be used to represent the direction of simultaneous flow of kilowatt and *reactive kilowatt* in the same circuit. This arrow may point in the actual direction of kilowatt flow. The kilowatt and *reactive kilowatt* quantities will then be marked beside the arrow. The kilowatt flow will be represented by a positive (+) quantity. The *reactive kilowatts* will be represented by a positive (+) quantity if its flow is actually in the same direction as the kilowatt flow, and by a negative (−) quantity if its flow is actually in the direction opposite to the kilowatt flow.

Application of the Conventions—Apparatus

If a generator, in parallel with other synchronous machines, is delivering active power only, an in-

crease in field current will cause it to generate (lagging) reactive power, while a decrease in field current will cause it to consume (lagging) reactive power.

For the station operator, it may be interesting and helpful to note here that, having standardized on lagging reactive power, and adopted corresponding instrument connections and labelling (see Fig. 2)

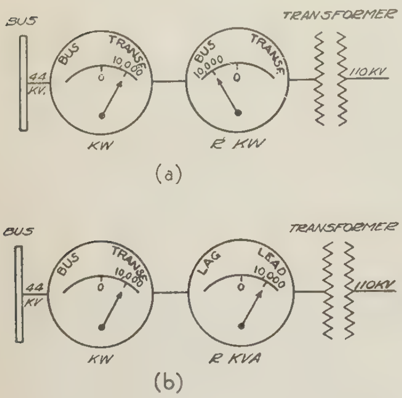


Fig. 3. Academic (a) and practical (b) methods of metering reversible circuits

Interpretation of readings under academic method requires knowledge as to how reactive kilovolt-ampere meter is connected with reference to kilowatt meter, i. e., whether "lag" and "lead" apply to power flow from bus to transformer or from transformer to bus. With the practical method this knowledge is not needed, all the information required being provided by the labelling of the meter scales

increasing the gate opening and increasing the field current of a generating unit operating in parallel with other synchronous machines have similar effects, in that the former causes an increase in kilowatt output (kilowatt meter pointer moves to the right) and the latter causes an increase in *reactive kilowatt* output (*reactive kilowatt* meter pointer moves to the right). Furthermore, it will be noted that the field ammeter pointer and *reactive kilowatt* meter pointer will always move in the same direction, that is, when one is moving from left to right, the other will also be moving from left to right, and vice versa. This consistency, uniformity, and simplicity are in striking contrast to the illogical and confusing inconsistency where the present "academic" standard marking and conventions are used, where lagging reactive output deflects the instrument pointer in the opposite direction from that of the field ammeter.

A synchronous condenser being a reactive power generator, a similar explanation applies. If the condenser is running at unity power factor (simply drawing kilowatts to supply internal losses), an increase in field current will cause it to deliver (lagging) reactive power to the circuit, while a decrease in field current will cause it to draw (lagging) reactive power from the circuit.

Unloaded transmission circuits have generally been said to be drawing leading reactive kilovolt-amperes but, according to the new conventions, we shall say they deliver (lagging) reactive power (*rkw*).

An induction motor draws (or consumes) (lagging) reactive power (*rkw*) from the circuit.

A static condenser delivers (lagging) reactive power (*rkw*) to the circuit.

Reactive Power (RKva) (*RKw*) Meter

In general practice, reactive kilovolt-amperes have been designated as being either "leading reactive kilovolt-amperes" or "lagging reactive kilovolt-amperes." Each of these, as above stated, can flow in either of 2 directions. On the other hand, active power (or simply power) has always been designated as just plain "kilowatts." In other words, in order to qualify a kilowatt meter reading completely, it has been necessary to state only magnitude and direction of flow, whereas, in the case of a reactive kilovolt-ampere meter reading, it has been necessary to state magnitude, kind (leading or lagging), and direction of flow.

Since, in this standardization, all reactive power will be represented in terms of lagging reactive power, both active power and reactive power values will be completely qualified by magnitude and direction of flow. "Reactive kilovolt-ampere" meters will now become "lagging *reactive kilowatt*" meters,

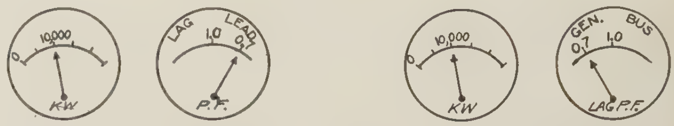


Fig. 4. Academic (a) and practical (b) use of 2-quadrant power-factor meters

(a). 10,000 kw flowing from generator to bus. Leading reactive kilovolt-amperes flowing from generator to bus. Ratio of kilowatts to total kilovolt-amperes is 0.7

(b). 10,000 kw flowing from generator to bus. "Reactive kilowatts" flowing from bus to generator. Ratio of kilowatts to kilovolt-amperes is 0.7

and their readings will always be in lagging *reactive kilowatts*.

RKw Meter With 2-Way Kw Meter

In metering a piece of apparatus whose kilowatt flow is always in the same direction, no trouble should be experienced. Now, let us consider a piece of apparatus whose kilowatt flow may be in either direction. In Fig. 3 is a transformer connecting a 110-kv system with a 44-kv system. Assume the reactive kilovolt-ampere meter (conventional scale markings) is connected to indicate correctly for kilowatt flow from bus to transformer. Under the conventional method shown in Fig. 3(*a*) the meters indicate that 10,000 kw and 10,000 leading rkva are flowing from the 44-kv bus into the 44-kv side of the transformer. If the reactive kilovolt-ampere meter read "10,000" to the left of the zero point, the readings would be 10,000 kw and 10,000 lagging rkva flowing from the 44-kv bus into the 44-kv side of the transformer.

In accordance with convention No. 1, previously stated, the markings on the reactive kilovolt-ampere meter will be changed to those shown in Fig. 3(*b*) the reactive kilovolt-ampere meter connections being reversed to produce this result. As before, the kilowatt meter indicates 10,000-kw

flowing from bus to transformer. The *reactive kilowatt* meter indicates 10,000 *rkw* flowing from transformer to bus.

It should be noted that, in Fig. 3(*a*) correct reactive kilovolt-ampere meter readings can be obtained only when the reader knows how the reactive kilovolt-ampere meter is connected, i. e., for which direction of kilowatt flow the reactive kilovolt-ampere meter markings "lead" and "lag" apply. On the other hand, with the new *reactive kilowatt* meter markings shown in Fig. 3(*b*) the reader never has to worry about instrument connections.

Power-Factor Meters

Power-factor meters where already installed may be treated the same as *reactive kilowatt* meters, as is shown in the following paragraph.

A power-factor meter really indicates direction of *reactive kilowatt* flow. In this standardization, the instrument will *always* be a "lagging power-factor meter." In other words, it will always be used to indicate the direction of flow of (lagging) reactive power. At the same time, of course, its scale is so calibrated as to give the ratio of kilowatt to kilovolt-amperes, regardless of the relative directions of kilowatt and *reactive kilowatt* flow. In Figs. 4 and 5 are illustrations. To obtain consistent meter labelling

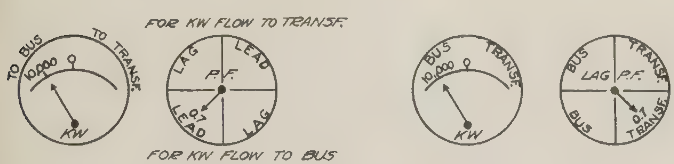


Fig. 5. Academic (a) and practical (b) use of 4-quadrant power-factor meters

(a). 10,000 kw from transformer to bus. Leading reactive kilovolt-amperes from transformer to bus. Ratio of kilowatts to total kilovolt-amperes is 0.7

(b). 10,000 kw from transformer to bus. "Reactive kilowatts" from bus to transformer. Ratio of kilowatts to kilovolt-amperes is 0.7

requires reversal of the conventional connections of the power-factor meter in each case.

Log Sheets and Diagrams

To illustrate the application of the conventions to log sheets, let us see how the readings of Fig. 3(*b*) would be recorded. The readings are 10,000 kw flowing from 44-kv bus to transformer and 10,000 *rkw* flowing from transformer to 44-kv bus. These readings would appear on the station log sheet as follows:

Circuit	Kw	*Rkw*
44-Kv Bus—Transformer No. 2	⟶ 10,000	⟵ 10,000

The instrument readings pictured in Fig. 5 would be entered in a log sheet as follows:

Circuit	Kw	Lag P.F.
Bus—Transformer No. 12	⟵ 10,000	⟶ 0.7

If the log entry for the condition pictured in Fig. 3(*b*) was to be transferred to a system diagram it would be written as shown in Fig. 6. In this method, having standardized on lagging *reactive kilowatts*, in diagrams lagging *reactive kilowatts* will be positive and leading *reactive kilowatts* (if ever referred to) will be negative.

Voltage Control

In a compact electrical system it is frequently possible to obtain satisfactory voltage control at substation busses by regulation of generator voltage. Generator voltage control will not, however, provide

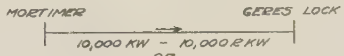


Fig. 6. Application of practical reactive power technique to diagrams

proper substation voltage regulation in an electrical system with long transmission lines. Additional facilities must be provided at some of the receiving substations to allow proper voltage control at these points. This voltage control is best provided in many cases by reactive power generators (synchronous condensers) at the receiving substations. In this application reactive power generators may be thought of as having 2 functions. One is the supply of the reactive power to the local load. This relieves the transmission system and power generators of the burden of the reactive power. The other function is that of sending reactive power back over the transmission circuits in the opposite direction for the purpose of voltage control. By this means a

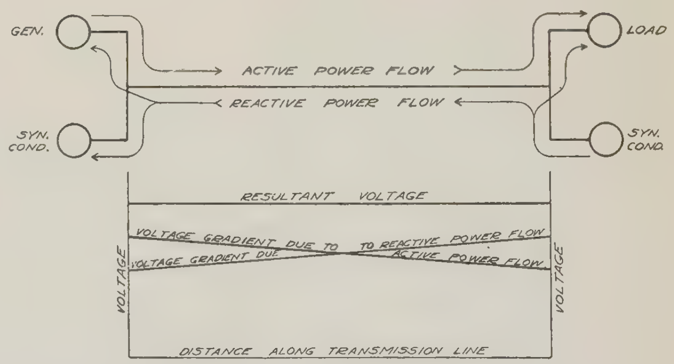


Fig. 7. Application of practical reactive power technique to system voltage control

Voltage gradients due to flow of active and reactive power compensate for each other producing practically flat voltage level

voltage gradient in one direction due to flow of active power may be compensated for by a gradient in the opposite direction due to flow of reactive power, thus making possible the maintenance of practically a flat voltage level over the whole system.

Consumer Metering

In consumer metering we are concerned only with what is taking place at a certain point in the circuit, namely, the point of delivery to the customer, and not at all with the questions of sources and control. For this purpose therefore the "academic" approach and technique are applicable. Present practices in metering customers which take large amounts of reactive power in proportion to their consumption of active power, may in some cases leave something to be desired, but it is doubtful if independent metering of the active and reactive components of the customer's load would be justified in many cases, since present rates doubtless are adjusted to an average situation from which only a few instances would widely depart. An inexpensive means of measuring kilovolt-amperes directly or measuring the arithmetic difference between the kilovolt-amperes and the kilowatts may ultimately prove useful in this field.

Conclusion

The "practical" conception of reactive power as herein outlined, in which the generation, metering, and control of active and reactive power are consciously divorced from each other, results in a simplified technique of power system operation which greatly facilitates the control of the system and the maintenance of maximum system efficiency.

III—Reactive and Fictitious Power

The single-phase and polyphase definitions of reactive power are considered in this article. It is shown that the single-phase definition is unsatisfactory with complex waves. The polyphase definition is better, but requires independent recognition of distortion and mesh distribution. A distinction is made between fictitious power and reactive power.

By
V. G. SMITH
ASSOCIATE A.I.E.E.

University of Toronto, Ontario, Canada

THE CONCEPTION of reactive power originated in the single-phase sinusoidal problem. In attempting to extend the idea to complex waves and multiple phase, certain difficulties arise which are well worth investigation. It is shown in this article that complex current and voltage wave forms render the usual single-phase definition unsatisfactory, and that although the polyphase definition is more satisfactory, it requires independent recognition of the effect of distortion and, in the case of 4 or more wires, mesh distribution. It is suggested that the geometric difference between the apparent power and the power be called the fictitious power to distinguish it from the reactive power which is only part of the fictitious power. Suggested definitions of the various kinds of power, written in the form of equations, are given.

Single-Phase Circuits

In the A.I.E.E. rules there are 2 definitions of reactive power, $\pm\sqrt{E^2I^2 - P^2}$ for single-phase and $\Sigma E_nI_n \sin \Theta_n$ for polyphase circuits, the summation extending over all harmonics and all phases. Applied to single-phase cases they cannot be reconciled except for sine waves or a load of pure resistance or its equivalent.

It may be shown[1] (for references see list at end of article) that

$$E^2I^2 - P^2 = \{\Sigma E_nI_n \sin\theta_n\}^2 + [\Sigma\{E^2_mI^2_m - 2E_mE_nI_mI_n \cos(\theta_m - \theta_n) + E^2_nI^2_m\}] = P^2_r + P^2_d \quad (1)$$

where P_r is the reactive power by the polyphase definition and P_d is the square root of the fourth term. This fourth term will vanish if the circuit presents the same impedance to all harmonics, i. e., if

$$\theta_m = \theta_n \text{ and } E_m/I_m = E_n/I_n \quad (2)$$

This quantity is due therefor to the distorting effect of the circuit and P_d may be called the "distortion" power. (In the Roumanian Questionnaire[2] it is called the "deforming" power but the word "distortion" is already well established in communication literature.) The relations between these quantities are shown in Fig. 1.

The idea of an algebraic sign is natural for sine waves and it is best to define leading reactive power as positive. Now the quantity $\pm\sqrt{E^2I^2 - P^2}$ may exist when there is no lead or lag but merely distortion.[3] In such cases which sign shall be used? On the other hand the quantity $\Sigma E_nI_n \sin \Theta_n$ has a definite algebraic sign depending upon the sinusoidal definition. Budeanu has called $P_f = \sqrt{E^2I^2 - P^2}$ the fictitious power. Apparently P_d

Full text (except for Appendix) of a paper "Reactive and Fictitious Power" (No. 33-57) to be presented at the Institute's North Eastern District meeting, Schenectady, N. Y., May 10–12, 1933.

and P_f may be taken as positive, no significance being attached to a negative sign.

The case of a sinusoidal voltage applied to a cyclically variable resistance is often quoted to show that $\sqrt{E^2I^2 - P^2}$ may exist when there is no electromagnetic energy storage, but it should be pointed out that $P_r = \Sigma E_n I_n \sin \Theta_n$ may also exist under the same conditions if the resistance cycle is unsymmetrical with respect to the voltage maximum. This would occur where there was heat storage. The reactive power P_r therefore is, in the most general case, an abstract mathematical quantity. [1] (When an opinion is expressed concerning one of the questions in the Roumanian Questionnaire the number of the question is given in square brackets.)

In spite of the fact that distortion and electromagnetic energy storage are inextricably mixed in the most general case, $P_r = \Sigma E_n I_n \sin \Theta_n$ is the best definition of reactive power yet proposed. It forms a symmetrical pair with $P = \Sigma E_n I_n \cos \Theta_n$, reduces correctly to the sinusoidal form in all cases, and determines the algebraic sign. Thus the reactive power of a neon sign with a resistor ballast is zero but the distortion power is not. As the phenomenon is really distortion it is surely better so to describe it. [9]

Polyphase Circuits

The reactive power $P_r = \Sigma E_n I_n \sin \theta_n$, has an immediate meaning in a polyphase circuit. The order of summation, over-phases or harmonics, and the point to which the potential differences are measured, are immaterial. However, it does not give complete information about the system. Fortescue[4] has suggested a definition based on symmetrical components but it is limited to sine waves and is too special to serve as a general definition. The fictitious power in polyphase circuits may be defined as $P_f = \sqrt{P^2_{ap} - P^2}$, where P_{ap}

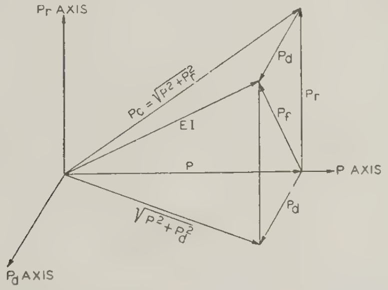


Fig. 1. Vector relation between power, reactive power, fictitious power, distortion power, and combined power in a single-phase circuit

is the apparent power. The only satisfactory definition of the apparent power is that of Lyon[5] and Liénard.[2] It is the maximum power obtainable when the phases and wave forms of the currents and voltages are varied in every possible manner consistent with Kirchhoff's laws, the effective values remaining constant.

Polyphase Circuits With Sine Waves

The reactive power $P_r = \Sigma E_n I_n \sin \theta_n$, is the natural definition with sine waves and is the one always used. It makes P_r the algebraic sum of the reactive powers of the load elements. Fictitious power can occur even with sine waves if the circuit is of 4 or more wires. This includes the case of the 3-phase 4-wire circuit.

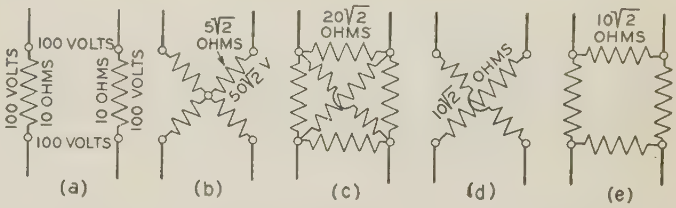


Fig. 2. An example of fictitious power in a 2-phase 4-wire mesh circuit

It may be shown that the stationary values of the power occur when each line current is in phase with or in opposition to the voltage from the corresponding line to some common point. Among these stationary values is the greatest power, P_{ap}.

The simplest type of load to meet these requirements is a star of positive and negative resistances with the neutral point as the common point in question. If it is possible to secure the given root mean square line currents by means of a star of all positive resistances, that star is unique and takes the greatest possible power, P_{ap}. Sometimes, however, it is necessary to introduce 1 or 2 negative resistances.

A mesh of pure resistances will not in general be such as to cause the line currents to be in phase with or opposed to the voltages to some common point. Consequently the power is less than P_{ap} and fictitious power, $P_f = \sqrt{P^2_{ap} - P^2}$, exists. It is not due to energy storage or distortion but to the distribution of the elements of the mesh and may be called the "fictitious mesh power." Meshes which are equivalent to some pure resistance star will not show fictitious power. Other meshes may show fictitious power on one voltage system and not on another.

A simple example in a 2-phase 4-wire circuit is shown in Fig. 2. Let (*a*) be the actual load and (*b*) the star which takes the same line currents. Both take 10 amp per line but in (*a*) the power is only 2 kw while in (*b*) it is $2\sqrt{2}$ kw. The fictitious mesh power of (*a*) is $\sqrt{(2\sqrt{2})^2 - 2^2} = 2$ kw. Circuit (*c*) is the mesh equivalent to (*b*) while (*d*) and (*e*) take the same power as (*b*) on the balanced voltages but would not in general take the same power.

In the case of 3 wires the mesh is a delta which may be reduced to a wye. A pure resistance delta can show no fictitious mesh power. In fact, it may be shown that the power is a maximum when the total reactive power is zero whether the load is a pure resistance or not and that the 3 line currents are then in phase with the voltages to a common point. The maximum power P_{ap} is $\sqrt{P^2 + P^2_r}$

for 3 wires, sine waves, and there is no such thing as fictitious mesh power in this case.

Polyphase Circuits With Complex Waves

It may be shown that the resistance star is the type of load which absorbs the greatest power when the wave forms are complex. In some cases 1 or 2 negative resistances may be necessary. All that has been said concerning meshes and fictitious mesh power in the sinusoidal case applies equally well here. The 3-wire case is again special and will show fictitious mesh power. When the mesh is not formed of pure resistances the distortion and mesh parts of the fictitious power are inextricably combined.

Measurements

The measurement of $\sqrt{E^2I^2 - P^2}$ directly would be very difficult but each quantity in it may be measured with considerable accuracy. The measurement of $\Sigma E_nI_n \sin \theta_n$ is theoretically possible by means of a series of perfect filters, provided the frequency were absolutely constant. In practice, the voltages are usually nearly enough sinusoidal and balanced that the method of applying a quadrature voltage to a wattmeter is sufficiently accurate. If the voltages are sinusoidal and balanced the wave forms and unbalance of the currents do not matter provided proper methods are used. No direct method of measuring the apparent power or the fictitious power in a polyphase network is known. The currents, voltages, and power may be measured and in some cases the apparent and fictitious powers calculated from them.

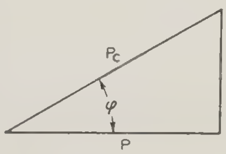


Fig. 3. Right-angled triangle connecting P P_r and P_c. In the proposed definition P_c would not equal VI and the angle φ would have no meaning apart from the triangle

Conclusions and Suggestions

The existing definition of reactive power in a single-phase circuit, $\pm \sqrt{E^2I^2 - P^2}$, leads to an unsatisfactory situation when the waves are complex. Any attempt to extend it in the form $\pm \sqrt{P^2_{ap} - P^2}$ to polyphase circuits leads to the conclusion that a pure resistance mesh must be considered to cause reactive power. This rules out the wattmeter method of measurement and provides no other in its place, a procedure to which metermen would strenuously object. Of course this is due to the Lyon-Liénard definition of apparent power, but what other definition is possible?

In spite of the difficulties of measurement the definition $P_r = \Sigma E_nI_n \sin \theta_n$ is much the better even for single-phase circuits. Distortion power and fictitious mesh power increase the losses the same as reactive power. If the polyphase definition is to be used it is necessary to recognize the effects of distortion and, in the 4-wire circuit, mesh distribution. [8.]

It is perhaps well to point out that the adoption of this definition will not increase the difficulties of measurement. Distortion and fictitious mesh power are there now but are neglected by the measuring apparatus; the new definitions merely would call attention to their existence.

The following definitions are suggested:

1. Reactive power $P_r = \Sigma E_nI_n \sin \theta_n$ under all conditions. This is the present polyphase definition. [14.]
2. The apparent power P_{ap} is the maximum possible power with the given effective voltages and currents. In the case of a single phase this is EI. [10.]
3. The fictitious power is $P_f = \sqrt{P^2_{ap} - P^2}$. [15.]
4. The combined power is $P_c = \sqrt{P^2 + P^2_r}$.
5. The power factor is $P/\sqrt{P^2 + P^2_r} = P/P_c$.
6. The reactive factor is P_r/P. This term has another meaning at present but is not much used.[6] [14.]
7. The distortion power in a single-phase circuit is
$P_d = \sqrt{P^2_f - P^2} =$
$\sqrt{\Sigma\{E^2_mI^2_n - 2E_mE_nI_mI_n \cos(\theta_m - \theta_n) + E^2_nI^2_m\}}$.
8. The distortion factor in a single-phase circuit is P_d/P.

It does not seem necessary to define fictitious mesh power as it is included in definition 3, of fictitious power.

Roumanian Questionnaire

Comments on some of the questions of the Roumanian Questionnaire[2] follow.

[2]. The form $VI \sin \varphi$ would have to be dropped entirely. A right-angled tirangle would still exist connecting P P_r and P_c, as in Fig. 3 but the angle φ would have no meaning apart from the triangle. The power factor would be $\cos \varphi$ and the reactive factor (new) $\tan \varphi$. [11]. The forms $P = P_c \cos \varphi$ and $P_r = P_c \sin \varphi$ exist but P_c is not VI.

[8]. It seems clear that the general case is too complicated to be described completely by the single term "reactive power." Distortion and fictitious mesh power are very difficult to determine and it would be advisable to separate reactive power from them for that reason. In addition there is the advantage of retaining an algebraic sign.

[12, 13]. By adopting an algebraic definition of reactive power all need for such terms as "inductive power" and "capacitance power" disappear. The former is negative and the latter positive reactive power.

References to Further Reading

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News

Of Institute and Related Activities

North Eastern District to Meet at Schenectady

THE NINTH annual meeting of the North Eastern District of the American Institute of Electrical Engineers will be held at Schenectady, N. Y., from Wednesday to Friday, May 10–12, 1933. Headquarters will be at the Hotel Van Curler at which all technical sessions will take place, with the exception of the session for Thursday morning, May 11. A program consisting of 4 technical sessions, inspection trips, annual dinner and dance, and entertainment features has been arranged by the committee; also there will be a students' session on Friday May 12. A special program has been arranged for women. The technical sessions will cover the following general subjects; namely, aeronautics, air conditioning, reactive power, and selected subjects.

Schenectady, situated on the Mohawk River, was originally settled by Van Curler in 1661. It is about 15 miles from both Albany, Capital of New York State, and Troy, N. Y., the 3 cities forming together what is generally known as the Capitol district. The city itself has a population of nearly 100,000 and is within easy reach of such well-known historic and scenic spots as Saratoga battlefield, Lake George, and the Adirondacks. Other well-known places are Cooperstown and Howe Caverns.

The city is the home of the American Locomotive and General Electric companies. The WGY broadcasting station is situated at South Schenectady. Union College, the oldest men's college in New York State, is within the city limits. In addition there are important representative concerns of the pulp and paper industries, carpet mills and textiles within easy reach. Of particular interest are the growing facilities of the Port of Albany, including a new high lift single span bridge from the City of Albany to Rensselaer, N. Y., and the largest grain elevator in the world.

The district is served by the New York Power and Light Company, which has recently completed a 132 kv tie line between Spier Falls and Poughkeepsie, N. Y., and a semi-outdoor synchronous condenser substation at Rotterdam Junction, near Schenectady.

Entertainment Features

On Wednesday night, a special entertainment will take place in Rice Hall featuring an interesting story, not generally known, concerning the early technical difficulties which were encountered in the invention of the present talking motion picture. This will include short exhibits among which will be an actual reproduction of the sound track taken from a recording by Walter Damrosch.

On Thursday night the annual dinner, including brief speeches by some distinguished guests, and novelty entertainment features will be held at headquarters and will be followed by the annual dance.

On Friday night, L. A. Hawkins and Oliver Ajar will give a group of General Electric research laboratory demonstrations, with special reference to electronic problems.

Those who enjoy sports are invited to make use of the facilities provided by the Mohawk Country Club and the Edison Country Club. Arrangements have been made so that visitors may make full use of these clubs upon payment of the usual greens fee. Both golf and tennis are provided.

Women's Entertainment

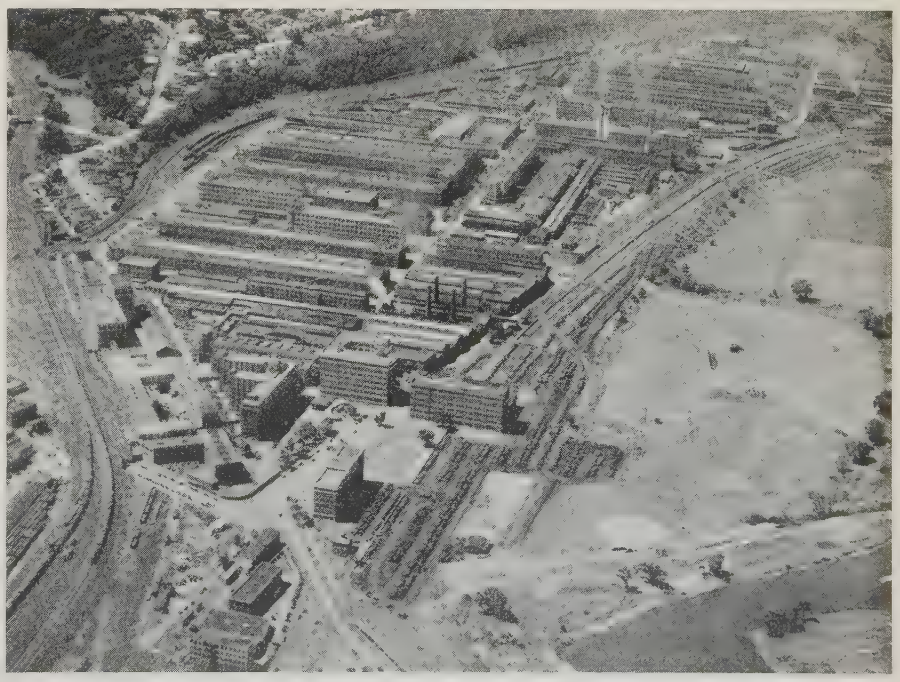
A special committee is preparing an interesting program for women visitors. A luncheon or tea, followed by bridge for those who so desire, is proposed for Wednesday, while for the remaining days visits to beauty spots in the surrounding country or other places of interest, have been suggested. Women will be welcomed at the local country clubs under the same conditions as men. Owing to the great popularity of golf and tennis in Schenectady it is hoped that women will avail themselves of the facilities during the special times set aside for women players by the committees of the 2 clubs.

Inspection Trips

Inspection trips are scheduled for Thursday afternoon and student inspection trips for Friday afternoon. A trip is being arranged through the Schenectady works of the General Electric Company, including the new outdoor mercury-steam-electric power station. For those who desire, trips to other points of engineering interest can be easily arranged.

Luncheons

On Thursday there will be a luncheon in the works restaurant of the General Electric Company, Building 48, prior to the inspection trips. A special luncheon for students is arranged for Friday. On other days luncheon may be obtained at popular prices at any of the following restaurants, all of which are in or near headquarters: the Hotel Van Curler main dining room and coffee shoppe, the Y.W.C.A. cafeteria, and the Alba Shoppe.



An airplane view of the Schenectady N. Y., works of the General Electric Company, which will be, without question, the principal point of interest to members and guests attending the forthcoming Schenectady meeting of the Institute to be held May 10–12, 1933

Registration and Hotel Reservation

All planning to attend this meeting should register in advance if possible. Cards for this purpose will be sent to all members of Districts 1 and 3. Members should complete their registration after arrival so as not to miss the opening session. There will be no registration fees.

Hotel reservations should be be made directly with the hotel preferred. Rates for the headquarters hotel, the Van Curler, for the Mohawk Hotel and for the Schenectady Y.M.C.A., which has accommodations for transients, are given in the accompanying table.

Hotel	Single	Double
Van Curler Hotel		
Without bath	\$2.50–\$3.00	\$4.00–\$5.00
With bath	\$3.00–\$5.00	\$5.00–\$9.00
Parlor suites	\$10.00 and	\$12.00
Mohawk Hotel		
Without bath	\$2.00–\$2.50	\$3.50–\$4.00
With bath	\$2.50–\$3.00	\$5.00–\$6.00
Y.M.C.A. (for men)		
No membership required		\$1.25

An information desk and bulletin board will be found in the Hotel Van Curler. Notices should be consulted.

Private automobiles may be parked in the grounds of the Edison Club (city division) opposite headquarters. During the day cars also may be parked in the General Electric parking field. The company's patrol department has set aside a special space for the use of visitors. Visitors using either parking space do so entirely at their own risk.

Program

Abstracts of all papers to be presented at the meeting are scheduled for publication in the May 1933 issue of ELECTRICAL ENGINEERING as they were not available in sufficient numbers for inclusion in this issue. Articles based upon 2 of these papers are presented on p. 262–70 of this issue.

All technical sessions except one, and the opening of the meeting, will be held at the Hotel Van Curler. The remaining session, for Thursday May 11, will be held in Rice Hall, in the Schenectady Works of the General Electric Company.

Wednesday, May 10

9:00 a.m.—Registration

9:30 a.m.—Opening Session

OPENING ADDRESS, J. A. Johnson, Vice-President, North Eastern District A.I.E.E., chief elec. engr., Buffalo Niagara and Eastern Power Corp.

Selected Subjects

THE ELECTRICAL CHARACTERISTICS OF IMPREGNATED CABLE PAPERS, C. L. Dawes and P. H. Humphries, Harvard University.

LOSS CHARACTERISTICS OF SILICON STEEL AT 60 CYCLES WITH D-C EXCITATION, R. F. Edgar, General Electric Co.

VARIABLE SPEED CONSTANT VOLTAGE D-C MACHINERY, Fred. B. Hornby, General Electric Co.

THE DESIGN OF TRANSFORMERS USED IN RESISTANCE WELDING MACHINES, H. E. Stoddard, Thomson-Gibb Electric Welding Co.

HOW ARE THE AMERICAN COLLEGES OF ENGINEERING TO ADAPT THEMSELVES TO THE CHANGED CONDITIONS IN INDUSTRY? V. Karapetoff, Cornell University.

2:00 p.m.—Aeronautics—F. M. Ryan, *Chairman*

RADIO AIDS TO AIR NAVIGATION, C. F. Green and H. I. Becker, General Electric Co. Special discussion of the paper by Messrs. Green and Becker, and a brief presentation of other developments in the field of aeronautics is being arranged.

8:00 p.m.—Special Entertainment Feature

Thursday, May 11

9:00 a.m.—Air Conditioning—A. R. Stevenson, Jr., *Chairman*

ELECTRICAL EQUIPMENT FOR USE WITH AIR CONDITIONING, L. Gwathmey and B. S. Weaver, General Electric Co.

ENERGY REQUIREMENTS OF VARIOUS TYPES OF AIR CONDITIONING APPARATUS, D. W. McLenegan, General Electric Co.

AIR CONDITIONING IN ITS RELATION TO RAILROADS, a talk by W. J. Madden, Pennsylvania Railroad Co.

AERODYNAMIC ASPECTS OF AIR CONDITIONING, a talk by S. M. Anderson, B. F. Sturtevant Co.

12:00 noon—District Executive Committee Luncheon, Tower Room, Building 48, General Electric Co.

12:30 p.m.—Luncheon, Works Restaurant, Building 48, General Electric Co.

2:00 p.m.—Inspection Trips.

6:30 p.m.—Annual Dinner, Hotel Van Curler.

9:30 p.m.—Dancing, Hotel Van Curler.

Friday, May 12

9:00 a.m.—Student Technical Session, Prof. L. W. Hitchcock, *Chairman, Student Counselors Committee*

12:00 noon—Luncheon Conference of Counselors and Branch Chairmen

2:00 p.m.—Student Inspection Trips

2:00 p.m.—Reactive Power—A. E. Knowlton, *Chairman*

REACTIVE AND FICTITIOUS POWER, V. G. Smith, University of Toronto.

REACTIVE POWER AND POWER FACTOR, W. V. Lyon, Massachusetts Institute of Technology.

POWER, REACTIVE VOLT-AMPERES, POWER FACTOR, C. L. Fortescue, Westinghouse Elec. and Mfg. Co.

OPERATING ASPECTS OF REACTIVE POWER, J. Allen Johnson, Buffalo Niagara and Eastern Power Corp.

NOTES ON THE MEASUREMENT OF REACTIVE VOLT-AMPERES, W. H. Pratt, General Electric Co.

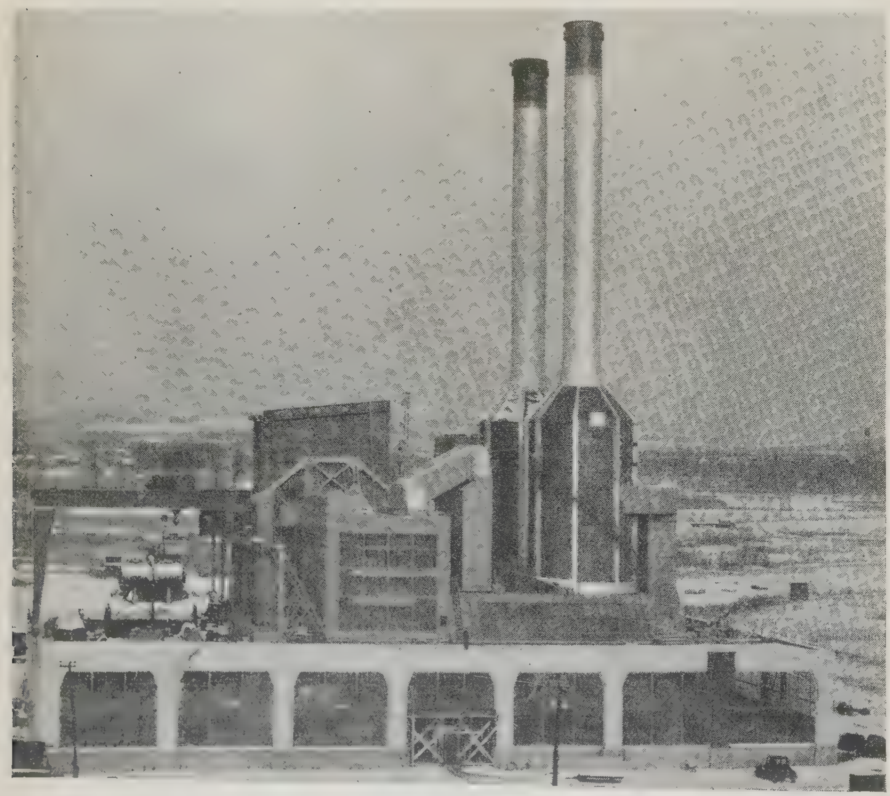
8:00 p.m.—Laboratory Demonstration

Saturday, May 13

The committee will be glad to make arrangements for golf matches between teams representing the visitors and the Schenectady Section, further inspection trips, informal meetings, or any other activities desired by visitors.

At the technical sessions papers will be presented in abstract, 10 min being allowed for each paper unless otherwise arranged or the presiding officer meets with the authors preceding the session to arrange the order of presentation and allotment of time for papers and discussion.

Any member is free to discuss any paper when the meeting is thrown open for general discussion. Usually 5 min are allowed to



Outdoor mercury-steam-electric power station, known as Building 265 of the General Electric Company's Schenectady, N. Y., works. This station will be inspected with considerable interest by those attending the Institute's forthcoming meeting in Schenectady, May 10–12

each discusser. When a member signifies a desire to discuss papers on other subjects or groups he shall be permitted a 5-min period for each subject or group.

It is preferable that a member who wishes to discuss a paper give his name beforehand to the presiding officer of the session at which the paper is to be presented. Copies of discussion prepared in advance should be left with the presiding officer.

Each discusser is to step to the front of the room and announce so that all may hear his name and professional affiliations.

Discussions at the technical sessions are not reported. To be considered for publication, discussions should be written and mailed to the A.I.E.E. Editorial Department, 33 West 39th Street, New York, N. Y., on or before May 26, 1933.

COMMITTEES

The committees handling the work in connection with the Schenectady meeting are as follows:

District Meeting—J. A. Johnson, *chairman*, vice-president, North Eastern District; A. C. Stevens, secretary-treasurer, North Eastern District; L. W. Hitchcock, chairman, Student Counselors, North Eastern District; C. W. Henderson, V. M. Montsinger, W. B. Hall, H. A. Maxfield, E. E. Johnson and H. H. Race.

Local—W. A. Terry, *chairman;* C. J. Koch, treasurer; S. A. Holme, publicity, sports, entertainment and dinner; H. M. Hartman, inspection trips; D. A. Yates, hotels and registrations; L. W. Hitchcock, student program; and Mrs. S. A. Holme, women's entertainment.

Hotels and Registrations—D. A. Yates, *chairman*, R. O. Shepp, J. A. Setter, D. B. Gearhart, and W. B. Potter.

Finance—C. J. Koch, *chairman*, W. A. Terry.

Publicity—S. A. Holme, *chairman*, F. A. Stortz, N. L. Hadley, and M. C. Hutchins.

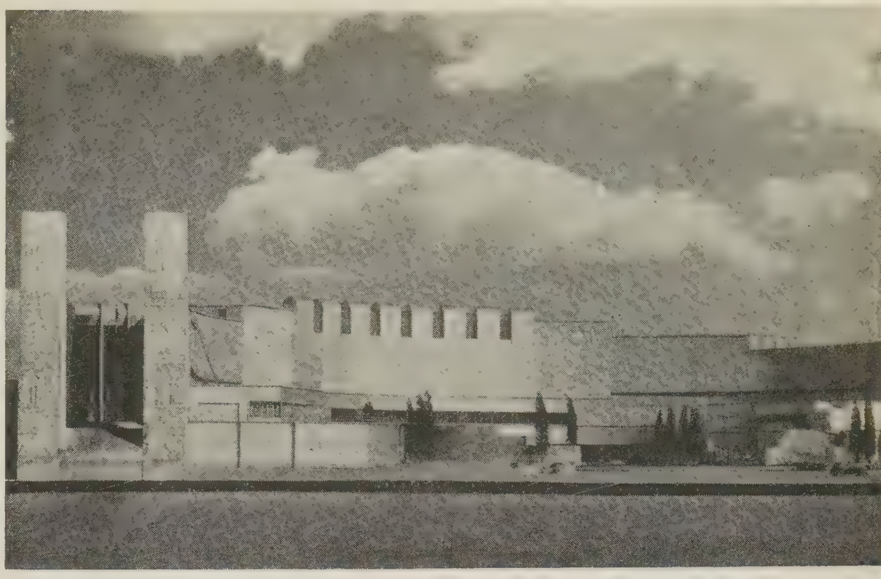
Inspection Trips—H. M. Hartman, *chairman*, C. E. Kilbourne, J. A. Jackson, S. Martin, Jr., I. A. Terry, and H. A. Winne.

Sports, Entertainment, and Banquet—S. A. Holme, *chairman*, G. L. Irvine, G. W. Moorhead, H. H. Handorf, R. A. Beekman, and O. F. Olsen.

Student Program—L. W. Hitchcock, *chairman*, W. B. Hall, E. M. Strong.

Women's Entertainment—Mrs. S. A. Holme, *chairman*, Mrs W. A. Terry, and Mrs. H. M. Hartman.

Chicago Exposition—a Summer Convention Attraction



EXHIBITS showing the generation, distribution, and utilization of electricity will be housed in the electrical building of the Century of Progress Exposition, to be held this summer in Chicago, Ill. This building is located on Northerly Island; in the communications building adjoining it on the north will be exhibits of telephone and telegraph communication. Modern electrical equipment of every variety will be housed in a series of section beneath an observation balcony in this building. Many pieces of equipment stated never to have left the manufacturers' research laboratories before will be shown to visitors. Among the many features is a diorama, or partly translucent painting illuminated to produce scenic effects, to be exhibited by the electric central station committee which represents 10 public utility groups. This diorama, 85-ft long, will represent the many uses of electricity. Also of interest will be the cascade of mysterious green and blue lights produced by $1^1/_2$ miles of gaseous tubes which will constitute the unique illumination effect on the windowless walls of the electrical building. The electrical building of the Chicago exposition, shown here, is only one of many buildings which will be inspected with much interest by those attending the Institute's 49th annual summer convention to be held in Chicago, June 26–30, 1933.

A.I.E.E. Executive Committee Meeting

In accordance with action of the board of directors, a meeting of the executive committee of the A.I.E.E. was held at Institute headquarters, New York, N. Y., March 15, 1933, in place of the regular March meeting of the board of directors.

Present were: H. P. Charlesworth, *chairman;* E. B. Meyer, W. I. Slichter, and C. E. Stephens of the executive committee; A. E. Knowlton and A. C. Stevens, members of the board of directors; and national secretary, H. H. Henline.

A report was presented and approved of a meeting of the board of examiners held March 14, 1933. Upon the recommendation of the board of examiners, the following actions were taken upon pending applications: 2 applicants were transferred to the grade of Fellow; 11 applicants were transferred and 3 were elected to the grade of Member; 106 applicants were elected to the grade of Associate; and 128 Students were enrolled.

The finance committee reported approval for payment of bills for the month of March amounting to $15,189.77. Report approved.

Approval was given to the dates, September 4–8, for the 1933 Pacific Coast convention, at Salt Lake City, Utah.

The committee approved the appointment by the president of the following committee of tellers to canvass, count and report upon the ballots cast for the election of Institute officers: J. B. Kelly, *chairman*, W. E. Coover, A. B. Covey, G. J. Lowell, C. S. Purnell, H. B. Stoddard, and E. Volckmann.

L. W. Chubb was nominated for appointment by the president of the National Academy of Sciences as a representative of the Institute on the division of engineering and industrial research of the National Research Council, for the 3-year term beginning July 1, 1933, to succeed Dr. C. E. Skinner, whose term expires at that time and who is ineligible for immediate reappointment. L. A. Ferguson was reappointed a representative of the Institute on the Commission of Washington Award, for the 2-year term beginning June 1, 1933.

Other matters were discussed, reference to which may be found in this or future issues of ELECTRICAL ENGINEERING.

Obtaining Unemployment Relief

Judging from the correspondence received by the secretary of the engineers' national relief fund, apparently many unemployed engineers throughout the United States are unaware that various forms of relief are available in their own communities. Practically every state, county, and city has raised or appropriated funds to provide for the relief of the unemployed. These funds are being expended in various ways.

Experience during the past months indicates that all engineers out of work and in need of assistance should first acquaint themselves with the local method of providing relief. This may be done by getting in touch with any of the following persons in their community: (1) officers of local sections of national engineering societies, (2) officers of local engineering clubs, (3) the city engineer, or (4) the county engineer.

If the member is so located as to be unable to reach any of the persons mentioned, a letter to the secretary of the engineers' national relief fund, 33 West 39th Street, New York, N. Y., will bring suggestions as to what seems to be the next best procedure.

Summarized Review of Some Winter Convention Discussions

PRINCIPAL discussion of the first 6 sessions held during the winter convention were summarized in ELECTRICAL ENGINEERING for March 1933, p. 200–202. Discussions of other sessions are presented herewith. The papers to which these discussions refer were abstracted in ELECTRICAL ENGINEERING for January 1933, p. 41–52, and February 1933, p. 122–24, excepting the papers given more complete treatment in these same or previous issues; additional articles based upon these papers are being presented in subsequent issues.

Only discussion submitted in writing in accordance with governing A.I.E.E. rules is summarized. Complete discussion together with all approved papers will be published in the TRANSACTIONS.

Rectifiers

High-Current Mercury Arc Rectifiers

J. J. Linebaugh (Schenectady, N. Y.) in his discussion of this subject explained that the ampere ratings of this unit give the designing engineer a better idea of the problems encountered than the kilowatt rating with overloads. To rectify such currents requires that the whole unit must be accurately and conservatively designed by careful balancing of vacuum, anode, and cathode currents per square centimeter, spacing, heat and voltage gradients, insulation, vacuum type tank, baffles, and adequate cooling to produce a satisfactory rectifier.

C. C. Herskind (Schenectady, N. Y.) also discussed this subject and pointed out that this high capacity unit extended the range and type of applications for which rectifiers are available. By utilizing the grids it may be operated to supply regulated d-c output, for inverting, for frequency changing and a number of other purposes. He also referred to the reliability of the unit which has been proved by considerable operation in actual service. Two of the units are operating in an electrolytic plant where they carry full load continuously.

Synchronous Mechanical Rectifier-Inverter

N. S. Hibshman (Bethlehem, Pa.) in his discussion presented curves and oscillograms showing that the static condenser is not essential to the operation of the rectifier. The condenser is rather to be considered as a means of relieving the duty of the quadrature third-harmonic voltage to the extent the economics of the particular case may dictate.

H. E. Kent (New York, N. Y.) discussed the subject from the standpoint of noise interference in telephone circuits caused by wave shape distortion. This can be reduced on the d-c load side of a rectifier by the aid of selective devices such as resonant shunts but, on the a-c supply circuits the problem is more difficult and no generally applicable solution has been found. He suggested that consideration be given to the wave shape during the development stage of new types of rectifiers and inverters.

Another discusser, J. J. Linebaugh (Schenectady, N. Y.) felt that the author had given an interesting analysis and description of the development but he believed that a great amount of work would be required to obtain a practical commercial unit even for fairly low voltages. He indicated that there are many difficult problems in the design of a mechanical rectifier commutator to take care of appreciable currents and it was his belief that such a commutator was still to be developed.

Insulation Coordination

H. K. Sels (Newark, N. J.) in a general discussion of the subject cited reasons why it would be advantageous to express insulation strengths in terms of voltage and time directly. He suggested that early agreement should be reached in expressing insulation characteristics by cathode ray oscillographs so that proper insulation levels may be selected by joint insulation coordination committees.

Impulse Testing of Commercial Transformers

F. W. Peek, Jr. (Pittsfield, Mass.) in his discussion of this subject was pleased at the rapid progress that had been made as indicated by the papers. He referred to his original suggestion in which he pointed out that "one of the most important problems in establishing lightning tests is to devise means for detecting incipient turn to turn, coil to coil or other failures." This is so because the operator must feel assured beyond any reasonable doubt that the transformer is as good after the test as before the test was made. It was believed worth while for the committee to give considerable attention to this subject.

H. V. Putman (Sharon, Pa.) discussed the work of the transformer subcommittee in relation to insulation coordination to clear up any misunderstanding on the part of some operating engineers. He explained that the committee was not trying to tell them how they should establish insulation coordination in their substations, what level of insulation they should use on their lines, and what level of insulation they should require in their transformers. He felt that the general problem of insulation coördination was largely outside the scope of the committee's activities and that it was only one small part of the transformer proper which they were endeavoring to handle.

In regard to the method of detection proposed by the subcommittee the discusser felt that it would indicate any major insulation failure to ground, any failure between coils, any failure lengthwise of an entire group, and a streamer of appreciable magnitude.

Another discusser, Philip Sporn (New York, N. Y.) believed that the report was a step in advance to put the question of transformer insulation and the entire problem of insulation coordination on a more rational basis. He emphasized, however, that almost everything recommended should be taken as a tentative recommendation. It was his belief that ultimate practice, when finally developed, would be considerably different from that recommended in the report.

The discusser cited that recommendations to confine tests to the positive wave, while giving more severe stress to transformer insulation, would be quite likely entirely misleading as a basis for coordination and give a very poor and possibly dangerous setup under certain operating conditions. Reference also was made to the brief treatment of the very important question of determining whether or not any damage short of breakdown occurs to any portions of the windings in the process of impulse testing.

Factors Influencing the Insulation Coordination of Transformers

C. L. Fortescue (East Pittsburgh, Pa.) explained that this paper presented the results of a series of tests to determine the approximate impulse time-lag characteristics of insulation of the type used in transformers. He cited that the data given in the paper was of great value to transformer manufacturers and it was his belief that the impulse time-lag curves were all the fundamental data needed for coordination and the use of the 1–5 and 1–10 waves should be confined to shop and laboratory investigations.

Another discussion by H. V. Putman (Sharon, Pa.) analyzed the value to the industry of the data presented in this paper. He cited that the author disclosed for the first time the shape of the time-lag curve for major insulation of transformers, its impulse rates, and the nature and effectiveness of the internal coordination which will be obtained with gaps of the conventional type. Furthermore, the paper establishes from fundamental data the reasonableness of the recommended coordinating gaps and constitutes the best possible argument for their acceptance by industry as the normal level of surge strength for the various voltage classes.

Philip Sporn (New York, N. Y.) in his discussion of this subject was not in agreement with 3 of the claims made in the paper. One of these claims was that the average time-lag curve of the major insulation of transformers is the same whether for positive or negative waves. The discusser believed the statement was not only not in agreement with the claims made in the paper, "Coordination of Insulation," but the data that the author furnished were most certainly not conclusive or adequate to back up the claim.

V. M. Montsinger (Pittsfield, Mass.) in his discussion compared some of the data and results presented in this paper with the data presented in the companion paper "Coordination of Insulation." He was pleased to note that the author's work confirmed a claim which he had made during the past 5 or 6 years; namely, that 60-cycle strength major insulation in a transformer bears a definite relation to the impulse strength. He pointed out, however, that this definite relationship applies only to the major insulation.

Coordination of Insulation

Edward Beck (East Pittsburgh, Pa.) in his discussion of this subject was in agreement with the authors' remarks regarding the undesirability of more than one insulation level for apparatus in a station. Another phase of this discussion cited that the coordinating gap was not a protective device, as it was usually thought of, for its operation is closely allied to flashover. The use of modern valve type arresters was advocated instead of gaps and gap combinations to furnish a coordinating device with flatter impulse characteristics. In closing, it was the discusser's opinion that coordination should be based on kilovolts measured by means of the cathode ray oscillograph.

C. L. Fortescue (East Pittsburgh, Pa.) analyzed the problem of coordination as based on the historical background of development and extended to the whole transmission system. He defined the term "coordination" as meaning nothing more than sound engineering in applying the data and knowledge that is available to obtain a layout that will give reliable service at the least possible cost. He remarked on how well apparatus insulation stood up in the past, which he felt compelled admission that there was then some degree of coordination carried out between apparatus insulation and substation insulation.

F. W. Peek, Jr. (Pittsfield, Mass.) in his discussion of this subject cited reasons which were based upon the data presented which lead to the following conclusions. The most effective protective system is: insulation levels as fixed by the coordinating rod-gap values; protective means, largely in the way of ground wires extending at least a few poles out from the station or towers for converting the direct stroke voltages into the traveling-wave type voltages; and lightning arresters. It might sometimes be desirable to add a gap of sphere-gap characteristics, particularly where ground wires are not used.

Another discusser, K. B. McEachron (Pittsfield, Mass.) referred to the part of the paper which showed that insulation as used in the transformer does not exhibit the degree of time lag in its breakdown which is shown by oil or air. He cited that thus it is not permissible to protect such insulation by a lightning arrester which has high time lag in its breakdown if steep waves, as from direct strokes, are to be allowed to reach the installation. This illustrated one of the important advantages of the thyrite station arrester whose compensated gap has a flat breakdown characteristic.

F. J. Vogel (East Pittsburgh, Pa.) in his discussion brought out the following additional points. In regard to the terms "outdoor" and "indoor" these seemed less expressive to him than "exposed" and "unexposed" to lightning surges. He also felt that there was an inconsistency in reasoning which suggests a single standard of insulation coordination in substations and then suggests different ones for potential and current transformers. The coordination levels for the instrument transformers, he believed, should be in accordance with the recommended standard circuit voltages.

Another discussion by H. V. Putman (Sharon, Pa.) emphasized the extensiveness and thoroughness of the laboratory work to obtain the data for this group of papers. It was believed the source of difference between competitive results would be found not in a lack of care on the part of either, but more in some difference in the fundamental standards employed by the 2 groups and on which their measurements must in the final analysis depend.

Impulse Voltage Testing

J. K. Hodnette (Sharon, Pa.) in his discussion of this subject brought out that the interconnection between the lightning arrester and secondary service grounds should be limited to cases where there are a number of dependable service grounds of low resistance in parallel. Lightning arresters occasionally become leaky or short circuit and primary current would flow to ground over the secondary service conductors. Otherwise, the ground resistance might be materially increased through the drying out effect of the leakage current with the result that primary potential would be on the secondary service lines.

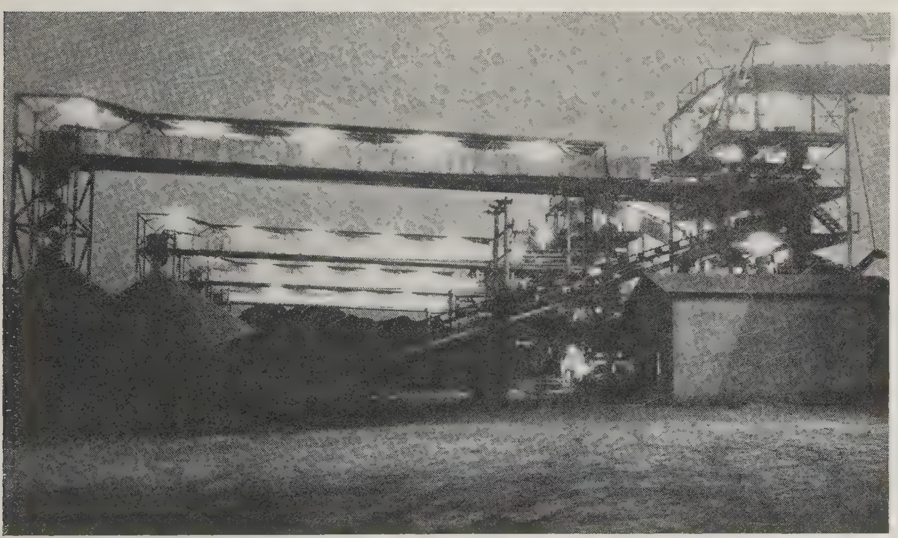
A. M. Opsahl (East Pittsburgh, Pa.) did not agree with the statement on page 3 of the paper that the voltage on the primary neutral, as illustrated in Figure 9B, is due to a failure in the primary winding. He did not believe this was so because there was no discontinuity in the voltage wave to show a spark in such a failure. He pointed out that the surge after being transmitted through the primary winding to the primary neutral would have the modified shape shown in Figure 7 with the somewhat higher voltage due to reflection.

D. W. Roper (Chicago, Ill.) in his discussion of this subject cited the success of a trial interconnection of the ground wires of lightning arresters and the grounded neutral main of the secondaries. Early in 1932 over 3,000 interconnections were installed in scattered locations affecting about 5,700 transformers. The records for 1932 indicate that a reduction of over 60 per cent in transformer troubles due to lightning was secured by this interconnection. Reference was also made to a similar trial installation elsewhere on 777 transformers without a single case of trouble with the customers' wiring on meters. In view of these successful trials and previous recommendations, it was suggested that such changes in the National Electrical Safety Code, as will permit this interconnection under proper safeguards, should be secured.

Protection of Rotating A-C Machines Against Traveling-Wave Voltages

Robert Treat (Schenectady, N. Y.) discussed this subject and it was his firm conviction that an intelligent application of the protective means suggested in this paper would generally reduce the probability of machine failure by an amount sufficient to entitle the protective equipment to be regarded as very cheap insurance. However, it should not reasonably be expected that 100 per cent protection can now be provided under all conditions.

Night Operation of Hoover Dam Gravel Plant



Westinghouse Photo

Construction at Hoover Dam has been expedited considerably by night operation of the aggregate plant. Gravel storage piles, stocking conveyors, stocking, and reclaiming towers are shown in this night view, the 11,000-440 volt substation being shown in the right foreground. Control of the flow of gravel for the entire plant is centralized at a pushbutton control tower located at the top of the tower in the discharge belt over the scalping screen. From this point the operator can view the entire plant. Careful interlocking of belts and screen trains prevents piling up of the material at any point. Under normal conditions, the equipment can be restarted only after the final delivery belts are started. Totally-enclosed self-ventilated squirrel-cage motors ranging in size from 5 to 150 hp, and a one hp wound-rotor cone-crusher motor, turn out 700 tons of raw gravel per hr.

K. B. McEachron (Pittsfield, Mass.) in connection with this subject cited several reasons why proposed methods of preventing reflections at the neutral would not sufficiently limit the stresses imposed. He believed the best method of preventing reflections at the neutral in the light of present knowledge appeared to be the use of a capacitor connected at the terminal of the machine and having sufficient capacitance so that the wave is sloped sufficiently to prevent the application of voltages higher than the machine strength as the result of neutral reflection.

Another discusser, J. F. Calvert (East Pittsburgh, Pa.) gave consideration to the use of the assumption that the armature winding may be treated as a transmission line or cable, but one which permits a very low velocity surge to propagate along it. He believed this scheme would give moderately accurate data on the voltages at the ends of the windings and, in the case of the delta-connected machine, at the mid-point of a phase as well. However, he did not believe it was at all accurate for other points in the winding.

Lightning

Recommendations for Impulse Voltage Testing

K. A. Hawley (Baltimore, Md.) in his discussion of this report pointed out just why it is desirable to make impulse tests with both positive and negative waves. He explained that the percentage of difference between positive and negative values varies considerably with different insulators. Although in general the limits of variation are not definitely known, he referred to some known cases in which the negative wave flashover of one insulator had been more than 30 per cent higher than the positive wave flashover.

Another discusser, A. O. Austin (Barberton, Ohio) also brought out that in providing protecting equipment the flashover values and time lags may be quite different for the positive and negative impulses. For this, as well as other reasons, the protecting gap should be adjustable if protection is to be provided with a minimum of trip-outs. A protective gap which can be adjusted not only to change the time lag but to regulate the time lag and flashover voltage for negative and positive impulses was presented by the discusser in a paper at the Milwaukee, Wis., meeting in 1932.

H. K. Sels (Newark, N. J.) in his discussion of this report referred to the previous report by the subcommittee on lightning arresters which recommended impulse waves for testing station type arresters. These tests were believed to be adequate for comparative purposes, but no indication was given of the protective capabilities of the arrester to protect equipment under service conditions. Whether traveling wave conditions with both voltage and current waves also were necessary in the testing of other equipment was a problem the discusser felt should be considered by the subcommittee.

C. L. Fortescue (East Pittsburgh, Pa.) believed that the 3 standard waves chosen in the report are satisfactory for the laboratory. He also felt that these waves were fairly representative of types of waves that may be expected to enter a substation connected with transmission lines.

F. J. Vogel (Sharon, Pa.) felt that the specifications in this report for the procedure of tests in the laboratory, under the heading "Testing Recommendations," were unnecessarily complicated. He cited that in a properly standardized laboratory, it should be possible to analyze once and for all the performance of the surge generator and to demonstrate the accuracy of the cathode ray oscillograph and divider.

C. M. Foust (Schenectady, N. Y.) discussed this report and he felt that it was factually sound, comprehensive, and forward looking. A word of caution regarding voltage-time breakdown curves was submitted. It was his belief that the so-called minimum wave flashover voltage-time curve, as shown in Fig. 6, had been credited with a wide significance which cannot be demonstrated by existing data regarding practical operating conditions or the mechanism of insulation breakdown.

Another discussion by K. B. McEachron (Pittsfield, Mass.) considered the tests proposed for lightning arresters. He felt it was possible to make tests on lightning arresters using the 3 waves proposed in the report, but to obtain appropriate current waves, he explained that the tests should be made on a transmission line.

F. D. Fielder (East Pittsburgh, Pa.) explained why they were not in agreement with several proposals made in the report. It seemed to them logical that the use of 3 different shapes of waves be eliminated to conserve laboratory time, especially since it is possible that minimum flashover values with waves of different tails can be obtained from specific points of the more complete time-lag curves. The enumerated testing recommendations were believed to constitute a laborious method and certainly not conducive to precise impulse measurements. They also did not agree with the proposed use of the sphere gap as a primary standard.

Lightning Investigation on Transmission Lines—III

I. W. Gross (New York, N. Y.) in his discussion of this subject called attention to the importance of considering both theory and practice. In view of the factors still unknown in the mechanism of a lightning stroke and its effect on a transmission line, theory alone might lead to erroneous conclusions. On the other hand, actual operating experience alone might be misleading, if results were not carefully analyzed and coordinated with theory.

A. E. Davison (Toronto, Can.) in discussing this subject questioned whether attempts to secur lightning proof lines were always the most economical methods by which the continuity of service can be attained. He suggested consultation of a physicist, or men who are qualified to study geophysical conditions with a view toward going around undesirable areas when projecting long lines.

Lightning Experience on 132-Kv Lines

Everett S. Lee (Schenectady, N. Y.) gave an interesting historical summation of lightning experiences from the time of Mr. Sporn's first paper which related the hectic experiences in 1925, up to the time of the present papers, all dealing with the experiences on the American Gas and Electric Company System. He pointed out the vast improvement noted in the present paper as compared to the early reports on operation by the same author. Steps in the development of apparatus and its application to the problems which brought about this improvement leading up to proposed standardization in terms of impulse voltages were concisely narrated in an interesting manner.

F. W. Peek, Jr. (Pittsfield, Mass.) discussed this paper in particular reference to Fig. 5 and the tower footing resistances. He believed it would appear that the particular outages affected by resistance were due to direct strokes since the lower values of resistance would not reduce the efficiency of the ground wire. He computed the order of the current range of the direct strokes, which, although very approximate, incidentally were of the same order as those obtained by direct measurements.

V. M. Marquis (New York, N. Y.) in his discussion described an additional means of checking the phase location of damage on transmission lines. This has been made possible by the development of the latest type of automatic magnetic oscillograph which overcomes slow starting characteristics and frequent changing of films. The new type oscillograph records all but about the first $^{1}/_{2}$ cycle of the follow-up current which gives a most definite and positive means for determining the phases in trouble and the sequence of events after the appearance of the dynamic follow-up current.

Studies of 26-Kv Wood Pole Transmission Construction

H. K. Sels (Newark, N. J.) in his discussion of this subject described a recent installation of fiber-tube protectors and installations of wooden-block protectors on the Public Service Electric and Gas Company system. Fiber-tube protectors are installed on every fourth pole and also adjacent to poles with potheads. A large difference in insulation level exists between poles with protectors which flashover at about 200 kv to ground, and unprotected poles, as the latter are unguyed and equipped with wooden crossarm braces giving flashover values to ground in excess of 1,000 kv. The wooden-block protectors were installed to provide some measure of lightning protection for 2 small outdoor substations. The work on both of these installations was not completed until late in the 1932 lightning season so that operating results are not yet available.

Wood Utilized as Lightning Insulation

In connection with this subject O. S. Hockaday (Fort Worth, Tex.) described his experiences with wood utilized as insulation. On a texas system of moderate capacity, 200 miles of 66-kv wood H-frame suspension-type construction was put into operation late in 1927, without any particular advantage being taken of the wood as insulation. After 2 years the construction was modified to utilize the wood in the structures as much as possible. This reduced the average number of insulator disks

required per year on account of burning from flashovers from 60 to 6. Another source of trouble attributed to ravens caused 42 trip-outs within a year. Gaps installed in the pole ground wires overcame this difficulty and since 1930, no trip-outs whatsoever have occurred which were known to have been caused by the birds.

Edward Beck (East Pittsburgh, Pa.) discussed this paper particularly in reference to the author's experience with drainage schemes involving arc interrupting devices. He explained that de-ion protectors have been manufactured for several years and, as a result of the painstaking development work it was possible either to pronounce an application unsuitable or to apply them with confidence. Consequently, the operating experience with these de-ion protectors had been good.

A. O. Austin (Barberton, Ohio) in his discussion of this subject pointed out several features which would permit the utilization of wood insulation to best advantage. He believed that operating records would go to show that a successful wood pole line may be built in several different ways, but the best operating systems generally would be simple in construction with the effective insulation of the wood developed to a maximum. The development of high flashover values and the limiting of normal frequency current, he felt, would do much to prevent trip-outs as most disturbances originate with a single-phase to ground fault.

Final Report Issued by Committee on Welded Rail Joints

DURING the past 10 years the committee on welded rail joints appointed by the American Bureau of Welding and the American Transit Engineering Association, has been engaged, with the cooperation of the U.S. Bureau of Standards, upon a study of welded rail joints. The purpose of the extensive investigation undertaken has been the improvement and standardization of methods of making these joints. The tests included conductivity, tensile, bend, drop, repeated impact and shear tests, as well as numerous metallurgical and miscellaneous investigations. All types of welded joints commercially used were tested and examined by the committee.

The results of this study, which have appeared from time to time in progress reports, are now presented in orderly arrangement in a volume issued under the date of September 1932. The report, a paper bound volume of 358 pages, may be obtained at a cost of $1 from the American Bureau of Welding, 29 West 39th Street, New York, N. Y. The volume is printed on 9 x 6 in. paper, contains many diagrams, charts, and tables.

A summary of the results of the investigations of the committee, as contained in the final report, is reproduced herewith:

Bar Weld

Conductivity Test—The electrical conductivity of the bar welded specimens (or joints) having a length of 3 ft was about the same as that of a plain rail having a length of from $2^1/_4$ to $2^1/_2$ ft.
Tensile Test—The ultimate tensile strength of the bar welded specimens ranged from 300,000 to 400,000 lb with an average of 370,000 lb.
Bend Test—Up to a load of about 75,000 lb the deflection of the bar welded specimen was about the same as that of a plain rail. For higher loads, up to 140,000 lb, the deflection of the bar welded specimens was much larger than for plain rails. Span between supports 42 in.
Drop Test—The bar welded specimens failed under from 1 to 3 blows. The average number of blows was 2.
Repeated Impact Test—The bar welded specimens withstood, on the average, 343,000 blows. With one exception, they failed through the middle of the bars. (Several way engineers report that "center breaks" seldom occur in service.)

Butt Joints

Conductivity Test—The conductivity test gave results equal to those shown by plain rail.
Tensile Test—In tension the butt joint stood an average of 870,000 lb which is of course, greater than any stress of this nature which it is likely to be called upon to meet in service. The breaks in tension indicate a clean, crystalline structure with the rail welded over its entire section. Some of the specimens developed the yield point of the rail material before breaking.

The ultimate tensile strengths of butt welded joints vary within 15 per cent from the average.

Some of the tests indicated that the use of current values around 1,500 amp gave better results than that of 1,600 or 1,700 amp. The lower current, however, was used in combination with a slightly greater heating time of 340 sec as against 275 sec used with the higher current. A metallurgical examination of the butt welded type of joint is given in progress report No. 3.
Bend Test—In the bend test a load of about 75,000 lb was necessary to cause a deflection of 0.1 in. which was practically the same as for the unbroken rail section.
Drop Test—In the drop test the failure occurred suddenly with very little deflection. The average number of blows to cause failure was 4 with the exception of 1 joint which stood only 2.
Repeated Impact Test—The repeated impact testing indicated that it took a relatively high number of blows to cause failure. In fact, for the average of 6 joints tested 1,029,000 blows were required to cause failure as compared with 1,116,000 for the unbroken rail. For most of the joints the fracture under the repeated impact test started in the web and then continued on either side of the joint. In 2 cases, however, the break continued partly through the rail section and partly through the weld.

The butt joint more nearly approached the quality of the original rail under physical tests than any other type of joint.

Cast Joints

Conductivity Test—The electrical conductivity of the cast welded joints having a length of 3 ft was the same as that of 3 to 4 ft of plain rail.
Tensile Test—Tensile strengths ran from 200,000 and 300,000 lb with an average of 247,000 lb.
Bend Test—In the bend test the joints showed a stiffness up to breaking point equal to the plain rail. At 75,000 lb the deflection was about 0.10 in.
Drop Test—In the drop test the average number of blows sustained was 3.
Repeated Impact Test—The cast welded joints withstood from 64,000 to 223,000 blows, averaging 119,000. This type of joint has not been in use for new welds for the past 12 years except in special trackwork where it is sometimes used in making compromise joints.

Thermit Joints

In making the Thermit joints tested by the committee the procedure followed was essentially that recommended by the manufacturer of materials used in making joints. Some of the joints were made with the usual separate inserts and others by the attached insert formed by undercutting the rail head. No essential difference was observed in the test results on the 2 types of joints.
Conductivity Test—The electrical conductivity was equal to that of the plain rail.
Tensile Test—The ultimate tensile strength of the Thermit joint ranged from 400,000 to 600,000 lb with an average of 510,000 lb. Failure in tension usually started with separation of the rail heads.
Bend Test—In the bend test approximately 80 per cent of the load was required to cause a deflection of 0.1 in. in a Thermit joint as compared with the plain rail.
Drop Test—The Thermit joints averaged 4 blows with the exception of one (not included in the average) which had a flaw in the base.
Repeated Impact Test—From 126,000 to 360,000 blows were required to cause failure with an average of 240,000 blows as against 1,116,000 for the unbroken rail. Usually the failure occurred horizontally through the web across the Thermit weld and then extended on the rail on either side of the joint.

The inspection of the broken Thermit welds showed that most specimens fractured through the rail near the weld, but where the fractures occurred through the head of the rail alongside of the insert, or between the rail heads themselves, a partial weld of the rail head was found in some cases.

Apex Joints

Conductivity Test—Conductivity of a 3-ft rail section including a joint was about equal to $2^1/_2$ to $2^3/_4$ ft of plain rail.
Tensile Test—The ultimate tensile strength of the Apex joints ranged from 150,000 to 200,000 lb.
Bend Test—Average failure occurred at 50,000 lb.
Drop Test—Most joints stood about 3 blows with only partial failure but with considerable deflection.
Repeated Impact Test—Average number of blows to initial crack 5,800.

Average number of blows to cause failure of $^1/_2$ of seam length on one end of joint about 26,000.

Seam Welded Type of Joint

Methods—When the committee first undertook its investigations a large variety of procedures were in force among the various street railways in making the seam welded type of joint. The welding processes were confined to 3 so-called methods: (1) carbon arc handfeed system, (2) carbon arc rod in position system, and (3) metal arc.

The results of the investigation showed that satisfactory results may be produced by each of these welding methods. However, the test data indicated that more uniform results could be expected from the carbon arc handfeed system and the metal arc system. In fact, these 2 systems only were used in all of the later tests. The tests demonstrate conclusively that the variable "human equation" was as large as, or greater than, any other variable and the committee recommends that only thoroughly trained, experienced operators be used for making the seam welded type of joints. To secure proper weld it is essential that suitable penetration be had at the root of the fillet weld. This penetration depends in some measure upon the type of joint plate used—it being easier to weld certain types than others.

Weld Deposited in 2 Layers—The investigation also showed that the metal should be deposited preferably in 2 layers. This conclusion has been substantiated by other investigations in the welding field which showed that the second layer refined the grain of the first layer and in a measure relieved the "locked-up stresses."

Staggering of Seams, Preheating, Postheating—In 3 out of 4 of the tensile tests of the "state of the art" series the joints broke at the end of the seams. Most if not all of the seams ended in about the same plane with reference to the cross-section of the joint. This type of fracture was believed partly due to eccentric loading and partly to notch effect. This led the committee to recommend and use in its subsequent or "development" investigation staggered seams. The amount of staggering used by the committee (approximately one in.) did not remove this difficulty although it somewhat lessened it.

Attention is called to the fact that in the preheating and postheating "development" experiments, the joints did not fail in the rail at the ends of the welds.

The tests rather definitely indicate that staggering of seams will reduce tendency of joints to break and the tests further indicate that preheating, postheating, or both may be desirable, but further tests along this line should be made.

In the tensile tests of the atomic hydrogen joints the failure was in the plates and weld rather than in the rails at the end of the welds.

It is significant to note that the "development" joints which were preheated or postheated required a much larger number of blows to cause complete failure under the repeated impact tests than those not receiving this treatment.

Base Plates—The value of base plates was not clearly demonstrated. In the repeated impact tests the welds holding the base plate broke at an early stage of the test and the plates dropped away from the joint, after which the joints failed in much the same way as joints not having these plates. On the other hand, in the tensile tests the base plates increased the tensile strength of the base of the joints to such an extent that failure was caused in the seams or the rail at or near the end of the fish plates. The ultimate tensile strength at which failure occurred was no greater than in the case where base plates were not used. The "development" tests planned for base plate joints were not carried out.

Joint Plate Design—In a number of the joints tested the design of the fish plates was such that good welding was practically impossible under service conditions. The committee recommends that, in general, fish plates be used which will facilitate penetration by the welder at the root[1] of the weld and which will readily permit the deposit of a weld of suitable cross-section.

[1] Root. The zone at the bottom of a cross-sectional space provided to contain a fusion weld.

None of the tests substantiated a need for greater refinements in the preparation of the exact contour of the surfaces to be welded provided the surfaces were readily accessible to the welder and were of sufficient size to permit deposit of a fillet weld with "legs"[2] of 0.5 in.

Electrical Conductivity—The electrical conductivity tests because of the greater cross-sectional area gave the highest results of any type of joint tested. Actual values for 3 ft in length were generally as low as for $2^1/_4$ ft of plain rail.

Tensile Tests—In view of the fact that a great many of the joints broke at the ends of the rail, conclusions as to the welding in the seams are difficult to draw. The shearing strength of good joints amounted to about 10,000 to 13,000 lb per linear in. of weld. The total tensile strength of the seam joint, assuming that the load would be equally divided among the various seams, would be of the order of 500,000 lb. However, equal loads do not come on the various seams in the tests. The lip top seam generally carries more than its share of the load as indicated by the stress-strain measurements. The Bureau of Standards has suggested that for a balanced design the seam lengths should be proportional to the areas for which they are to transfer loads from rail to rail. Only one joint was made up with the lengths of weld such that their centroid coincided with the centroid of the rail section. However, this joint having only half length base seams did not break in the welds and withstood a greater load than other specimens of the same series welded at room temperature with the metal arc. It is suggested that this subject merits further study.

From the point of view of tensile strength the tests indicated that the seam welded joint is an excellent joint. (Average value, 390,000 lb.)

Inasmuch as practically all of the metal arc seam welded specimens failed in the tension tests at the ends of the welds, it is suggested that staggering of the joint seams or partial annealing of the structure be employed where tension failures are encountered in service. It is interesting to note that one of the joints made by the carbon arc handfeed system failed at 810,000 lb which was practically equal to some of the resistance butt welded specimens. In this joint 2 operators welded from diagonally opposite ends of the joint simultaneously starting on the head seam. This might be a subject for future investigation.

Bend Test—In the bend tests the seam welded joints offered as much or more resistance to bending than a plain rail as in nearly all cases a load of 75,000 lb was required to cause a deflection of 0.1 in. Joints with base plates required a load of approximately 100,000 lb to cause this same deflection.

Drop Test—All types of seam joints tested under the drop test stood an average of 3 to 4 blows except those of series 15 which averaged 3 to 4 times that number. Joints of series 15 were the only ones preheated but the detailed description of the tests shows that substantial failure occurred at about 5 blows on an average with progressive seam failure before destruction of the plates.

Repeated Impact Tests—In the repeated impact tests many of the joints broke through the plates with little or no apparent injury to the welds to the extent of about 50 per cent of the "state of the art" series and 70 per cent in the "development" series. It is significant to note, however, that in the "development" series where fracture occurred in this way most of these joints began to fracture and also completely failed at a much lower number of blows than those in which there was some or considerable breaking of the welds. We are forced to the conclusion, therefore, that for the joints which broke in the plates there must have been some initial stress in these joints or "notch" effect or else that initial seam failure relieved the stress in the plates of those joints which ultimately failed in the seams.

[2] Leg. One of the fusion surfaces of a fillet weld.

In interpreting the repeated impact tests great care must be taken. Often the total number of blows should be disregarded as the test may have been continued long after the joint had failed as a structure capable of carrying a load. Similarly the number of blows to cause the initial crack may not be a fair criterion of the ability to stand up under test. It is necessary to study the complete test. It is difficult, if not impossible, to assign a figure that would be equivalent to the "elastic limit" in a tensile test, but a figure indicating the beginning of the crippling stage of the test would be the best criterion of the resistance ability of the joint.

It is interesting to note that for the "state of the art" series in those joints which failed at a relatively high number of blows, some device was used to relieve the stresses or to insure a deposit of sound ductile weld metal. (See Table I.)

General

Stresses—In a series of tests in which a street railway car dropped off varying heights of shims placed on the rail joints up to shims of 0.16 in. thickness, the maximum stress was 10,200 lb per sq in. in the lip of the welded joint without a base plate. The stress produced by the car dropping off this height of shim was similar to those produced in the repeated impact testing machine with a weight of tup of 400 lb dropping a distance of 1 in. on joints placed on supports 22 in. apart. In most of the investigational work the height of drop was 6 in. which produced stresses approximately $2^1/_2$ times that pro-

Table I—Joints From the "Present State of the Art" Series Where at Least One Seam Failed for Half Its Length on One Side of the Joint

Joint No.	No. of Blows to Cause Fracture of a Seam for $^1/_2$ Its Length on One Side of Joint	No. of Blows to Cause Destruction	Significant Facts Concerning Joints
2-2	51,000	72,400	Weld deposited in 2 layers
2-3	70,000	138,100	Use of flux
4-6	70,000	98,000	Use of flux
5-9	188,000	330,500	Use of flux
8-1	5,000	39,200	Two operators welding each seam from diagonally opposite ends of joint
8-5	70,000	215,800	
14-6	200,000	264,000	Postheating of first and second layers with the arc. Preheating by the arc before welding
14-12	28,000	129,300	
15-12	123,000	163,200	Preheating by torch
15-14	132,600	189,900	
15-30	15,200	108,900	
15-31	47,200	105,100	
15-36	6,400	230,200	
21-1	12,000	228,100	Use of flux
21-2	37,700	168,100	
21-3	63,100	203,800	
25-1	64,500	142,000	Peening of weld metal
25-3	31,100	161,200	
25-4	79,300	202,200	

duced by the car under the conditions noted above.

One seam welded joint was tested with this 1 in. drop and withstood a repetition of 4,861,600 blows before final breaking.

Preheating—The series of metallurgical examinations made for the committee indicates that a preheating temperature of 900 deg F is desirable when joints are preheated in preparation for welding.

These methods vary considerably and apparently are all more or less effective. Some of these are: (1) two operators welding from diagonally opposite ends of the joint simultaneously on each seam, (2) preheating or postheating or both in various ways,* (3) peening each layer, (4) use of flux.

It is interesting to know that some of the other tests indicated corresponding increase in quality of these joints. For example, attention is called to comments under "Drop Test" for those joints that were preheated or postheated or both.

The matter of preheating and postheating is one that requires careful consideration. In some tests reported by the Rail Welding and Bonding Company and described on p. 123–30 of progress report No. 3, relatively poorer results were obtained.

* See methods used in making joints of 15 series, progress report No. 2, p. 37–8, and the 14 series, progress report No. 3, p. 62–3.

Illuminating Engineering Society Convention.—The 27th annual convention of the Illuminating Engineering Society will be held during the week of August 28, 1933, at Camp Illumination, Lake Lawn Hotel, Delavan, Wis., located in the Chicago summer resort area. This convention will be known as the Chicago World's Fair convention. There will be a preconvention session under the auspices of the lighting service committee of the society on Monday, August 28, followed by the regular convention sessions from August 29 to 31, inclusive. A special visit to the Century of Progress International Exposition is being arranged for Friday, September 1, with special programs and an inspection trip under the guidance of those responsible for one of the most extraordinary showers of light ever displayed on the American continent. For those registering at the convention who wish to come earlier or stay later to make a thorough tour of the Century of Progress Exposition, arrangements will be made for special hotel and lodging facilities in the loop of Chicago.

Equations for Vacuum and Gas-Filled Lamps.—Research paper No. 502 published by the U.S. Bureau of Standards entitled "Characteristic Equations of Vacuum and Gas-Filled Tungsten-Filament Lamps" by L. E. Barbrow and J. F. Meyer (A'08, M'13) is for sale by the superintendent of documents, Washington, D. C., at a price of 5 cents. The paper is reprinted from the Bureau of Standards *Journal of Research,* v. 9, December, 1932, p. 721–32. Equations are presented in this paper which describe the characteristics of miniature lamps as well as large lamps. Tables of characteristic relations included furnish means for ready calculation of light output, current, power input, and operating frequencies over a wide range of voltages and lamp sizes.

Letters to the Editor

To Institute Members Planning Trips Abroad

Members of the Institute who contemplate visiting foreign countries are reminded that since 1912 the Institute has had reciprocal arrangements with a number of foreign engineering societies for the exchange of visiting member privileges, which entitle members of the Institute while abroad to membership privileges in these societies for a period of 3 months and members of foreign societies visiting the United States to the privileges of Institute membership for a like period of time, upon presentation of proper credentials. A form of certificate which serves as credentials from the Institute to the foreign societies for the use of Institute members desiring to avail themselves of these exchange privileges may be obtained upon application to Institute headquarters, New York. The members should specify which country or countries they expect to visit, so that the proper number of certificates may be provided, one certificate being addressed to only one society.

The societies with which these reciprocal arrangements have been established and are still in effect are: Institution of Electrical Engineers (Great Britain), Société Française des Electriciens (France), Association Suisse des Electriciens (Switzerland), Associazione Elettrotecnica Italiana (Italy), Koninklijk Instituut van Ingenieurs (Holland), Verband Deutscher Elektrotechniker E. V. (Germany), Norsk Elektroteknisk Forening (Norway), Svenska Teknologforeningen (Sweden), Stowarzyszenie Elektrykow Polskich (Poland), Elektrotechnicky Svaz Ceskoslovensky (Czechoslovakia), The Institution of Engineers, Australia (Australia, Denki Gakkwai (Japan), and South African Institute of Electrical Engineers (South Africa).

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

An Appeal for Cooperation

To the Editor:

To people who have spent any considerable portion of their lives in foreign countries, any idea of the engineering profession having outstripped the consumptive capacity of the world, by too much machine efficiency, must seem slightly ridiculous, to say the least. All the talk about over-production of goods being in any way related to the present depressed state of business, and of the necessity of shorter working hours, and a slowing up of the development of labor-saving devices as a means toward rectifying this condition, is too provincial in its outlook to merit any serious consideration. Let us have more and better and more intelligent production. Far from being over-crowded, the markets of the world are for the most part struggling along on a basis next door to starvation.

Looking at things from the standpoint of the average resident of the United States, where real poverty is a thing almost unknown, one might be pardoned for thinking markets are glutted, and that no demand for goods exists. For the most part, people are well dressed, well fed, and have excellent housing accommodations, with conveniences of life which many people in foreign countries scarcely know are in existence. But even in the United States, when we get down under the surface of things, we see a potential demand for goods, which would be sufficient to stagger the productive capacity of all the factories of the country, if only it could be let loose, by supplying it with sufficient purchasing ability in the form of money, or in most cases, of credit. And when we add to such potential demand at home, even a small part of that of foreign countries, in which thousands and thousands and thousands of people actually lack shoes to cover their feet, and clothes to properly cover their bodies, and proper food to nourish them—if in the face of facts like these we can ever twist our mental point of view to believe that goods are, or ever have been over-produced in this world—there certainly must be something radically wrong with such point of view.

As to shorter working hours, if economic conditions can be so shaped as to permit these to the mutual advantage of all interested, by all means let us have them. But let the engineers keep on with the good work of cheapening the world's output of goods, until there is enough and to spare, for every last inhabitant of the earth. And by the time that is done, based on present conditions, the need will have increased so enormously, that they will be able to start all over again and do it anew: for it is the wants and desires of mankind which make the wheels of business turn. And the wants of the human animal are just about infinite in their capacity and diversity, provided the standard of life is one which will permit appreciation of the advantages and conveniences of goods turned out. And the higher the standard of living, the more diversified becomes the demand, and with constantly expanding capacity to absorb.

The real problem before the business and financial world is how to raise and to improve the standard of life of the masses of the world continually, supplying them with sufficient purchasing power to keep business

on an even keel, and with constantly increasing demand. This, in a nutshell, is what is required. But to get it means reaching out into so many fields, and touching so many interests, including such things as politics, morals, finance, and above all, the innate selfishness of man, that one may well despair of securing any real solution for the world in general. "No man liveth unto himself, and no man dieth unto himself"—and this is true of nations as well as individuals. The economic conditions of the world are on an international basis, and will never be truly ironed out, until such time as there is more brotherly love among the peoples of the world, and less disposition to believe all foreigners as villains, thieves, and cutthroats. In this connection, it is always well to remember that we, ourselves, are just plain foreigners to the other fellow, whose hopes, desires, and ambitions, in the final analysis, are pretty much the same as our own.

But while the world economic problem is much too involved to hope for any early solution, this is not true of the United States of America. The really surprising thing about the whole matter is that any crisis exists, or has existed in this country. When one stops to consider that 92 per cent of the entire business of the country is domestic, and only 8 per cent foreign, one may well give pause to wonder why 120,000,000 people should so tie themselves up in a knot, just because the rest of the world got that way, and when only a beggarly 8 per cent of their business interests have anything whatever to do with the rest of the world. The United States is, for all practical purposes, a self-contained country. The resources are so enormous, and so varied, that with proper control and development, it is hard to see why any situation should seriously affect the country, even if the rest of the world should be entirely upheaved and in anarchy.

Why then, if this be the case, has the United States been so hard hit, along with the other nations? It is possible that the purchasing power of the rank and file of the people of the world in general is not sufficient to absorb goods at present in existence. But it can scarcely be claimed that goods on hand in the United States are excessive. For the past 10 years, practically all business has been run on what is called a "hand-to-mouth" purchasing policy, and with normal buying power available, all stocks could be quickly absorbed. What is the cause of reduced purchasing power? In the final analysis, it is due to human greed more than to any other cause; greed on the part of manufacturers for larger sales, and greater profits; greed on the part of labor for more and bigger wages; greed on the part of sales executives, in selling to excess on the installment plan, thus robbing present markets of their normal sales expectation; greed on the part of consumers in buying things they might be unable to pay for; greed on the part of capitalists for bigger returns on their investments; and greed on the part of speculators for unearned profits, and a life without effort on their part.

While self-interest is the very foundation stone of the present individualistic system which is the basis of our economic life, it is the selfishness and greed of a few individuals which are undermining and wrecking the system. These individuals are not specific people, because we are all more or less tainted with the disease of selfishness; and given the power which these individuals have through money, the chances are that about 9 out of 10 of us would do just about the same as they do, should the opportunity present itself. As an example of this, it is quite often the most bitter and outspoken radical against capitalism who becomes the most oppressive employer when circumstance and good fortune transfer him to the capitalist class. What is needed is more cooperation and good-will among competitive capitalists, and more sympathy and understanding between labor and capital, together with a greater sharing in the wealth produced, on the part of the workmen producing it. We are accustomed to think that ownership of productive tools gives the owner the right to all profit remaining after expenses have been paid. This is very questionable; because a laborer or mechanic, in addition to selling his labor at so much per day, gives of his own free will interest and loyalty to his employer, and many other intangibles, all of which enter into the value of the product, the profits of which fall to the employer and not to the laborer. Factories where good-will, interest, and loyalty prevail in relations between employer and employee, undoubtedly can turn out goods cheaper and better than factories where the opposite conditions exist. Therefore these items supplied by labor have a definite cash value to the employer, part of which should be passed on to the employees. "The laborer is worthy of his hire," and the signs of the times would suggest to discerning capitalists that he ought to get a bigger and more intelligent proportion of his hire, if the present individualistic system is to continue, with all its desirable benefits.

Many people today are becoming impatient with the capitalistic or individualistic system, and believe that socialism or communism will give the working class more advantage than they enjoy under the individualistic system. Socialism is a beautiful theory, but just as long as men are selfish and dishonest, just so long will socialism fail when put into practice. The record of all cooperative municipal enterprises, most of which operate under socialist principles, is all that is necessary to refer to to prove this. And communism needs no exposing to any one that has any brains whatsoever, and uses them to even a faint degree. Everybody that thinks at all, knows that the individualistic system, especially in a democratic country such as the United States, offers the maximum of reward and of liberty of action for effort put forth. The individualistic system is undoubtedly full of abuses, due to "Man's inhumanity to man," but it is by all odds the best system for men who can stand on their own feet and be men, because it is based on one's own self-interest in himself. It is the best system both for capitalists, and particularly for labor. But it would be an infinitely better system if both capital and labor were less selfish, and more generous in their attitude, one to another.

Very truly yours,
E. I. Brown (A'31)
(Apartado 46, San Luis Potosi, Mexico)

Graphical Determination of Symmetrical Components

To the Editor:

In the "Letter to the Editor" from R. Laplante, published in the December 1932 issue of Electrical Engineering, p. 886–7, entitled "Graphical Determination of the Symmetrical Components in a 3-Phase Unbalanced System," I notice 2 errors.

The first one, in the initial paragraph, is an error commonly made as a result of confusing the significance of the words rotation and sequence, or order. Mr. Laplante states that: "An unbalanced 3-phase system may be resolved into 3 sets of symmetrical components which are: 2 balanced 3-phase systems of *opposite rotation* and a uniphase component."

Convention and use have established the counterclockwise direction of rotation as the standard rotation for vectors used in the solution and representation of electric and magnetic circuits. In Figs. 1 and 2 there are shown 2 systems of vectors, counterclockwise rotation, but of opposite sequence or order. In Fig. 1 the projections of the 3 vectors upon the X-axis (or upon the Y-axis if the latter is chosen as the axis of reference) reach a positive maximum in the order or sequence A, B, C, which is the standard alphabetic order; this is called the positive or direct phase sequence or order. In Fig. 2 the projections reach a positive maximum in the sequence or order A, C, B; this is the negative or reverse phase sequence or order.

With these facts in mind, I should like to suggest that the paragraph be corrected

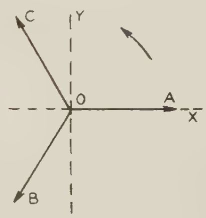


Fig. 1

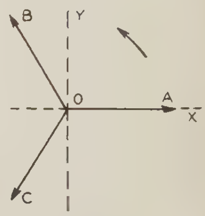


Fig. 2

to read: "... which are: 2 balanced 3-phase systems of *opposite sequence or order* and a uniphase system."

In Fig. 6 of the same letter, the direct or positive phase sequence system is shown to have the order or sequence A, C, B, and the reverse or negative phase sequence system as having the sequence A, B, C, in contradiction with Fig. 3 of the same letter, which is correct.

Very truly yours,
John B. Troja (A'32)
(Student, Ohio State University, Columbus)

Graphical Determination Symmetrical Components

To the Editor:

In the December 1932 issue of Electrical Engineering, p. 886–7, a letter was published concerning the graphical solution of unbalanced 3-phase systems. While doing some work on the same problem recently I happened onto a very simple graphical solution. As far as I can determine, the solution is original, and as such may be of interest.

For simplicity of explanation, it is presented in 2 diagrams. Actually, of course, a single diagram would be sufficient and would not become involved.

Let A, B, and C be the vectors of a 3-phase system, whose sum is not zero. In Fig. 1 they are added and the resultant vector divided by 3 to give the zero sequence component of the system. This component is subtracted from the 3 original vectors, resulting in A', B', and C', which add up to zero.

A', B', and C' are now plotted from a common point, as in Fig. 2. Next B' is rotated 120° positively (as denoted by $B' \angle +120°$) and C' 120° negatively (as denoted by $C' \angle -120°$). The ends of the vectors will be equidistant from each

other. Now a circle is described through these 3 end points and its center connected to the points, giving vectors A_2, B_2, and C_2. These represent the negative sequence component of the original system, but in reverse phase order. The vector A_1 joining

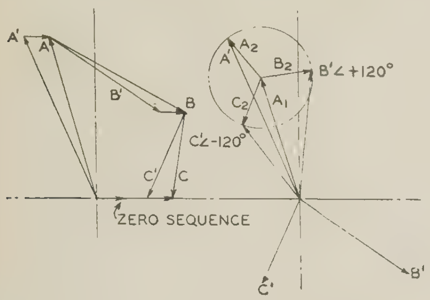


Fig. 1 Fig. 2

the center of the circle to the origin represents the positive sequence component A^+. Also B^+ is obtained by rotating A_1 through 120° negatively and C^+ by rotating A_1 through 120° positively.

So much for the simple mechanism and construction of the solution. A proof of that portion of the construction which follows the elimination of the zero sequence component is as follows:

From Fig. 2 as drawn

$$A' - A_2 = B' \angle + 120° - B_2 = C' \angle - 120° - C_2 \text{ by identity.} \quad (1)$$

We know that in a 3-phase system of 2 symmetrical components that

$$A^+ = B^+ \angle + 120° = C^+ \angle - 120°,$$

which may be expressed as

$$A' - A^- = B' \angle + 120° - B^- \angle + 120° = C' \angle - 120° - C^- \angle - 120° \quad (2)$$

Eqs. 1 and 2 each represent 2 separate equations

$$A' - A_2 = B' \angle + 120° - B_2$$
$$A' - A_2 = C' \angle - 120° - C_2$$
$$A' - A^- = B' \angle + 120° - B^- \angle + 120°$$
$$A' - A^- = C' \angle - 120° - C^- \angle - 120°,$$

which may be solved simultaneously to determine values of A_2, B_2, and C_2 which will make Fig. 2 a solution of a 3-phase system. The solution of these equations is not given here, but the resulting relations are actually found to be

$$A_2 = A^-$$
$$B_2 = B^- \angle + 120°$$
$$C_2 = C^- \angle - 120°$$

This proves that A_2, B_2, and C_2 represent the negative sequence components, and are in reverse phase order.

From Fig. 2

$$A' - A_2 = A_1$$

But we know that in a 3-phase system

$$A' - A^- = A^+$$

Then, since $A_2 = A^-$,

$$A_1 = A^+,$$

which proves the position of the positive sequence vector. By similar methods it may be shown that, from this vector, B^+ and C^+ are obtained by proper rotation.

A quick check on the graphical work is furnished by measurement of the angles between the negative sequence components, which should be 120° each. This check is valuable.

By similar methods to those shown above, this solution may be applied to n-phase circuits. In such a case the circle for the negative sequence will be determined by n points all equidistant from their adjacent points.

Very truly yours,
HENRY BACKENSTOSS
(Enrolled Student)
(Massachusetts Institute of Technology, Cambridge, Mass.)

Pipe Line Pumping and Automatic Control

To the Editor:

An Article "Pipe Line Pumping and Automatic Control" by John Fies appeared in ELECTRICAL ENGINEERING for January 1933, p. 29–34; this article was the full text of a paper presented at the A.I.E.E. winter convention, New York, N. Y., January 23–27, 1933.

In connection with the subject covered by this excellent article, Figs. 1 and 2, showing panels for controlling a remotely controlled crude oil pumping station which has been in operation almost 2 years, may be of interest. The station is fully autmoatic in that the 3 motor driven pumps start, stop, and run fully protected by electrical devices. It is remotely controlled from the dispatching office about 15 miles away. The panel in this office is shown in Fig. 1, the panels in the station being shown in Fig. 2.

The control switches and indicating lamps on the office panel are mounted on an etched plate (etching not clearly shown in photograph) laid out to represent the piping of the station relative to the main line. The dispatcher has control and supervision of the station valve—a large motor operated valve equipped with limit-switches and indicating interlocks. He is also able to start or stop any of the 3 pumps at will. The protective devices in the station not only protect the equipment in the station but send individual indications to the dispatcher. By this means, he is able to not only know the cause of the trouble, but is able quickly to dispatch the necessary remedy.

Another interesting feature of this installation is in the method of bringing the suction and discharge pressures into the office so that a continuous record is obtained over the same 2 telephone-size line wires used to control the equipment. On the office control panel are 2 series of 10 lights each, arranged in a circle, each lamp having a small card-holder adjacent telling the pressure it represents. One series represents the intake or suction pressure while the other series represents the discharge pressure. Normally, the equipment is stationary but if the pressure changes, the new indications are sent to the office in the form of impulses to change the lamp indications. The contact-making pressure gages for sending the impulse from the station are shown mounted above the station switchboard at the extreme right. They are motor driven devices which are relayed through small low-torque contacts on the pressure gages.

All of the switching equipment in the station, with the exception of a few protection devices, are mounted in a room adjacent to the pump room where it is not necessary to have special construction to insure freedom from explosions. It is necessary to so protect those few protective devices which by their duty makes it imperative to mount them with the motor driven pumps.

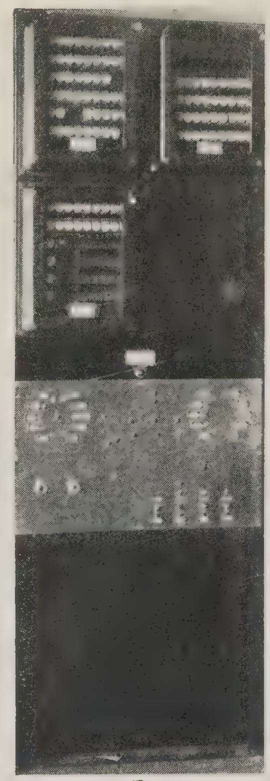


Fig. 1. Office panel

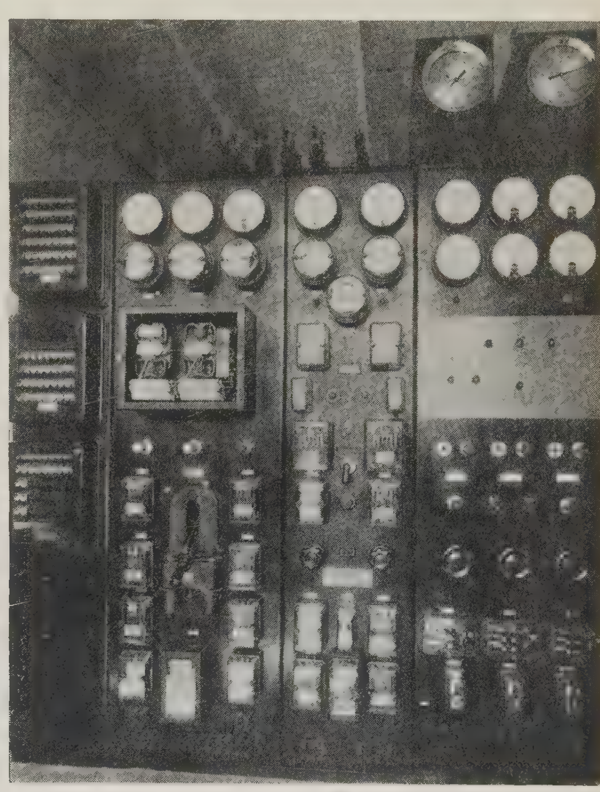


Fig. 2. Station panels

Very truly yours,
M. E. REAGAN (M'30)
(Section Engr, Switchboard Engg Dept., Westinghouse Elec. and Mfg. Co., E. Pittsburgh, Pa.)

Personal

Edward Weston (A'84, M'84, Member for Life, and past-president) chairman of the board, Weston Electrical Instrument Corp., Newark, N. J., has been awarded the 1932 Lamme Medal of the A.I.E.E. The medal, which will be presented to Doctor Weston at the summer convention of the Institute to be held in Chicago, Ill., June 26–30, 1933, was awarded him "for his achievements in the development of electrical apparatus, especially in connection with precision measuring instruments." Doctor Weston was born in Shropshire, England, in 1850, and received his formal education in that country. From boyhood he was devoted to experiments in chemistry and electrometallurgy. Although, because of parental wishes, he studied medicine for 3 years, his keen interest in electrical and mechanical investigations claimed his spare time. Coming to New York City 1870, he spent a year with a small firm of manufacturing chemists, then became chemist and electrician with the American Nickel Plating Company, and from 1872 to 1875 maintained a nickel plating business of his own. He made many material contributions to the practice of electrotyping and nickel, gold, and silver plating; he also developed practical and economical methods for electrolytic copper refining. In 1875 he became a partner in the firm of Stevens, Roberts, and Havell, of Newark, N. J., to engage in the manufacture of dynamo-electric machines for electroplating, electrotyping, and electric lighting. This business was incorporated in 1877 as the Weston Company, and in 1881 was consolidated with the U.S. Electric Light Company, of which Doctor Weston served as electrician until 1888. His first U.S. patent on dynamo

EDWARD WESTON

construction was filed in 1876; later he received many patents in this field. During the period from 1875 to 1886, he also was engaged in intensive development of both incandescent and arc lighting. At this time he encountered in all his researches great difficulty in making the necessary electrical measurements with the clumsy, slow acting instruments then available; he therefore developed and built for his own experiments a set of more practical instruments. These were so successful that in 1888 he decided to relinquish his other interests and devote all his time to the research and development necessary to produce accurate and convenient electrical instruments. He established the Weston Electrical Instrument Company, of which he was vice-president and general manager from 1888 to 1905, and president from 1905 to 1924, when he became chairman of the board. His achievements in developing instruments of a high degree of accuracy and portability are well known. His knowledge of chemistry was valuable in this field in the development of alloys with practically zero temperature coefficients, and his alloys are now used in virtually all kinds of electrical measuring instruments. In 1908, the Weston standard cell was accepted as the universal standard of electromotive force. Doctor Weston was a charter member of the Institute, and a member of the first board of directors. He held offices in the Institute as manager 1884–87, president 1888–89, and vice-president 1889–91. His memberships in other scientific and engineering societies include The American Society of Mechanical Engineers, American Electrochemical Society, American Physical Society, American Chemical Society, Franklin Institute, and American Association for the Advancement of Science (Fellow). He was elected an honorary member of the Franklin Institute in 1924, and received the honorary degrees of doctor of laws, McGill University, 1903; doctor of science, Stevens Institute of Technology, 1904, and Princeton University, 1910. In 1929 Doctor Weston presented to the Electrochemical Society, a fund for the establishment of a fellowship in electrochemistry; this fellowship of $1,000 is awarded by the society on March 1 of each year to a candidate showing marked capacity in carrying out research in electrochemistry or its applications. Doctor Weston's interest in the younger members of the profession is shown in the terms of this fellowship, which provide that the candidate must have completed an undergraduate course and be under the age of 30 at the time of the award.

C. J. Thomson (A'27) now erecting engineer for the General Electric Company, is one of the 31 General Electric employees who, this year, received the Charles A. Coffin Foundation award. His experience is perhaps more colorful than that of any other in the entire group. In 1924 he hitch-hiked from Oakland, Calif., to Schenectady seeking a new job; in 1931 the General Electric Company sent him to Russia to supervise the erection of the water-wheel generators on the Dnieprostroy hydroelectric project; and in 1932 the Soviet government conferred upon Mr. Thomson and 2 other Americans, one of them Col. Hugh L. Cooper, the order of the Red Banner of Labor in recognition of his services. The electrical equipment which he erected is said to be valued at $3^1/_2$ million dollars.

C. H. Champlain (A'28) formerly works manager, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., has been appointed general works manager of the company. In his new position Mr. Champlain will supervise the management and operation of the nation-wide plants of the Westinghouse Company. He started with this company in 1898 as a machinist at East Pittsburgh, being made assistant foreman a few months later. In 1903 he became general foreman in charge of the manufacture of industrial and railway motors. For 12 years he had charge of various divisions of the works devoted to the manufacture of electrical equipment. In 1915 he was placed in charge of munitions manufacture at East Pittsburgh, later being transferred to East Springfield, Mass., to be general superintendent of the works there, in charge of the production of rifles for the Russian government, and later, when the United States entered the World War, of Browning machine guns. In 1919 he returned to East Pittsburgh as assistant works manager; 4 years later he was sent to Sharon, Pa., where he organized and built the factory for the manufacture of transformers. After 8 years at Sharon he was again transferred to East Pittsburgh, this time as works manager, in 1931. He now becomes manager of all works of the company.

C. H. CHAMPLAIN

F. A. Moss (A'12, M'12) engineer, Thomson Research Laboratory, General Electric Company, West Lynn, Mass., is one of the General Electric employees receiving the award of the Charles A. Coffin Foundation for 1933. Doctor Moss, designed and introduced the centrifugal supercharger for reinforcing airplane engines. This equipment is used on practically every military, naval, and transport airplane in the United States. This apparatus is one of the highest speed devices of modern times, the impeller of the supercharger commonly attaining a speed of more than 30,000 rpm.

F. H. Gale (A'04) manager of conventions and exhibits of the General Electric Company, Schenectady, N. Y., has been retired at his request after 43 years of service with the company. He will continue in general charge of arrangements for the General Electric Company's participation in the Century of Progress Exposition, to be held in Chicago, Ill., this summer, until the exposition is opened to the public in June.

J. G. DeRemer (A'07, M'13) who has been engaged in research engineering in New York, N. Y., has become associated with Glenn Muffly in the development of

"off-peak" electric refrigeration. Mr. DeRemer previously had done considerable development work in connection with refrigerators. He was a member of the Institute's meetings and papers (now technical program) committee 1916–17, power stations (now power generation) committee 1916–17, of which he was chairman, and Sections committee 1916–17.

A. E. Kennelly (A'88, F'13, and past-president) professor emeritus of electrical engineering at Harvard University, Cambridge, Mass., was elected president of the Metric Association at the recent annual convention in Atlantic City, N. J. Doctor Kennelly also was elected to membership in the International Committee of Weights and Measures, at its meeting in Sèvres, France, in January, 1933.

H. D. Brown (A'25) an electrical engineer with the General Electric Company, Schenectady, N. Y., is one of the employees receiving the Charles A. Coffin Foundation award of that company for 1933. For 10 years, Mr. Brown has been working at the task of bringing the mercury arc rectifier to its present high degree of practical efficiency.

G. B. Shanklin (A'16, M'29) engineer of the cable section, central station department, General Electric Company, Schenectady, N. Y., is one of the employees receiving the award of the Charles A. Coffin Foundation for 1933, for his contributions to the present practice in high-voltage oil-filled underground electric cables, used in various localities up to a maximum of 132,000 volts.

F. R. George (A'13, M'25) engineer of operations, Pacific Gas and Electric Company, San Francisco, Calif., has been appointed to succeed himself as the A.I.E.E. representative on the Engineering Societies Employment Committee. Mr. George has served continuously on this committee since its organization in 1923.

G. A. Richardson (A'08) president of the Chicago Surface Lines, Chicago, Ill., has been made receiver for the Chicago Railways. The Chicago Railways Company and the City Railway Company are the principal units comprising the Chicago Surface Lines.

Francis Blossom (A'02, M'13, Life Member) member of the firm of Sanderson and Porter, New York, N. Y., has been designated by the American Engineering Council as one of its representatives on the National Trade Recovery Committee.

Farley Osgood (A'05, F'12, and past-president) consulting engineer, New York, N. Y., has been designated by the American Engineering Council as one of its representatives on the National Trade Recovery Committee.

E. C. Jones (A'12, M'14) secretary of the Crocker-Wheeler Electric Manufacturing Company, Ampere, N. J., has been elected a director of that company to fill a vacancy.

Thomas Fitzgerald (A'02) vice-president and general manager, Pittsburgh Railways Company, Pittsburgh, Pa., has been reelected president of the Western Pennsylvania Safety Council.

Obituary

Nelson Levi Pollard (A'07, M'13, F'13) consulting electrical engineer of the Newark, N. J., office of the United Engineers and Constructors, Inc., died March 3, 1933. He was born in this country in 1868, and in 1896 graduated from the State University of Nebraska, with the degree of B.S. in E.E. From 1897 to 1898 he was electrician for the St. Louis and Suburban Railway Company, St. Louis, Mo., and for the following year was in the testing department of the General Electric Company. From 1899 to 1903 he was electrician and steam engineer for the Colorado Springs and Cripple Creek District Railway Company, Cripple Creek, Colo. For 2 years ending in 1905 he was electrical engineer in the switchboard engineering department of the General Electric Company of Schenectady, N. Y., and for one year was construction engineer for this company at Mecaxa, Mexico. In 1906 he jointed the organization of Ford, Bacon and Davis, New York, N. Y., as electrical engineer. Since 1907 he has been with the Public Service Electric Company, Newark, N. J., and its succeeding organizations, the Public Service Production Company and United Engineers and Constructors, Inc. Between 1909 and 1912 he held the position of assistant engineer, and from 1912 to 1922 was electrical engineer. On the incorporation of the Public Service Production Company in 1922 he was made consulting electrical engineer of this organization, and upon the organization of the United Engineers & Constructors, Inc., in 1928, continued as consulting electrical engineer of the Newark office of this latter company. Since Mr. Pollard entered the service of the Public Service Corporation of New Jersey at the beginning of its fifth year, in 1907, he has seen the company grow in generating capacity from approximately 50,000 kva to its present total of 747,000 kva, and the transmission voltage raised from 13.2 kv to 132 kv, with interconnections at 220 kv. The installed substation capacity has increased to more than 40 times that when Mr. Pollard began his service with the organization. Mr. Pollard has been active in the committee work of the National Electric Light Association, serving as a member of the electrical apparatus committee. He was an active member of the New Jersey Society of Professional Engineers and Land Surveyors. He also has been active in the committee work of the A.I.E.E., having been a member of the protective devices committee 1914–26, 1928–30; electrical machinery committee 1924–27; and board of examiners 1920–27. He was the author of Institute papers on protective devices in 1916 and 1923, and had contributed many discussions.

Roy Morgan Stanley (F'23) electrical engineer, Byllesby Engineering and Management Corporation, Chicago, Ill., died March 7, 1933, at his home in Western Springs, Ill. He was born at LeRoy, N. Y., in 1876, and graduated from Cornell University as an electrical engineer in 1898. From 1898 to 1901 he was draftsman and estimator for McIntosh A. Seymour & Company, engine builders, and for 8 years following this was associated with Westinghouse, Church, Kerr and Company. From 1903 to 1907, he was draftsman and superintendent of construction, testing, etc., for Sargent & Lundy, following which he was for a short period with the Corn Products Company, as draftsman and designer, and with W. L. Fergus & Company, consulting engineering. From 1909 until the time of his death he was associated with the Byllesby Engineering and Management Corporation. As assistant electrical engineer and designer during the first part of this period, he made reports on public utility properties and was engaged in the design and estimating of transmission and distribution systems, substations, and electrical portions of power stations. Following 1918 he was responsible for all electrical work of the Northern States Power Company, and was also responsible for electrical engineering, designing, and construction of substations and electrical portions of steam-generating stations for the Louisville Gas & Electric Company, Louisville, Ky. In recent years Mr. Stanley was placed in charge of the electrical work for other Byllesby properties, having considerable to do with the Standard Gas & Electric Company properties, and the Duquesne Light Company, Pittsburgh, Pa. His experience in these fields has enabled him to effect many economies and introduce innovations, among which were several features in the application of truck type panels in distribution substations. He was a member of the Institute's automatic stations committee 1928–29. He also was the author of several Institute papers including the subjects of low voltage a-c and primary network fault ground busses, miniature switchboard supervisory automatic control, and similar subjects.

Henry Allen Sinclair (A'90, M'96, F'12, and Member for Life) retired, died at his home in Mystic, Conn., February 13, 1933. Mr. Sinclair, a pioneer in the electrical illumination field, was born in Springfield, Mass., in 1856. From 1874 to 1887 he was at the U.S. Ordinance Proving Ground, Sandy Hook, N. J., part of the time as assistant and later as electrician, connected with all kinds of experiments made there. In 1887, he joined the organization of the Tucker Electrical Construction Company, New York, N. Y., first as assistant and later as electrician in charge of all electrical lighting work. He also had general

charge of the design of plants and the preparing of specifications for the work undertaken by this company. He later became secretary and treasurer of this company, continuing in these positions for 39 years. Mr. Sinclair served as treasurer of the New York Electrical Society for 25 years.

Louis N. Stoskopf (A'22) general manager of the long lines department of the American Telephone and Telegraph Company, New York, N. Y., died at his home February 18, 1933. He was born in Toronto, Ontario, Canada, in 1884, and was educated in the public schools and by technical studies carried on at home. In 1905 he entered the employ of the American Telephone and Telegraph Company at Chicago, Ill., as telegraph repeater attendant. In 1910 he was transferred to Beaver Dam, Ohio, in charge of the test station for this company, and in 1911 was placed in charge of the Chicago test station. In 1914 he became division superintendent of service for the fourth division of the company with headquarters at Chicago, and in 1915 became district plant superintendent for the state of Ohio with headquarters at Cleveland. In 1921 he was transferred to the long lines department of the company in New York as service supervisor. In 1924 he was made general plant manager for the long lines department, and in 1930 became general manager of this department for the entire system. Mr. Stoskopf was a member of the Telephone Pioneers of America, and of the Shelter Rock Country Club.

Local Meetings

Student Conference Held at Knoxville

Thirty-five counselors and chairmen of the student branches in the Southern District of the A.I.E.E. and Vice-President W. E. Freeman met at a Student activity conference, December 3, 1932, at Knoxville, Tenn. J. G. Tarboux presided as chairman. He appointed E. A. Bureau to act as secretary of the meeting.

A motion was carried that the conference meet next year at Raleigh, N. C. A motion also was carried that Prof. R. S. Fouraker of North Carolina State College be made district chairman of student activities for next year.

The subject of attracting student membership to the branches was discussed. The matter of papers presented in competition at the conference became the next subject of discussion; the following was passed: "No Branch shall submit more than 2 papers to the papers committee for any meeting." A number of other motions were passed referring to the presentation of papers and awarding of prizes.

Future Section Meetings

Boston

April 11—Progress of 50 Years in the Electrical Industry, by Dr. A. E. Kennelly, Harvard Univ.

May—Annual dinner and entertainment.

Cleveland

April 20—Joint meeting with Case Sch. of Ap. Science Branch.

May 18—Annual dinner meeting. Speaker—H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc.

Dallas

April 25 at Dallas Pwr. & Lt. Auditorium. Arc Phenomena and Circuit Interrupters, by Dr. Joseph Slepian, Westinghouse Elec. and Mfg. Co.

Detroit-Ann Arbor

April 18 at Detroit Edison Auditorium. Modern Theories of the Composition of Matter, by Prof. A. H. Compton, Univ. of Chicago.

May 16 at Lansing, Mich. Advances in Lighting, by Prof. H. H. Higbee, Univ. of Mich.

Fort Wayne

April 18—Recent Development in Transportation, by W. M. Guynes, Genl. Elec. Co.

May 16—Electric Refrigeration and Air Conditioning, by Chester Lichtenberg, Genl. Elec. Co.

New York

April 6—Transportation group.

April 14—Power group. This meeting will be held in the Brooklyn Edison Company auditorium and will include an inspection of the research laboratories and the Hudson Avenue station.

April 18—Illumination group.

April 28—General Section meeting and Student Branch convention. An all day program is being arranged, the morning and afternoon to be devoted to inspection trips and special features for students only, while the evening session will include, in addition to the competition for the student prizes offered by the Section, a talk by W. E. Wickenden, president of Case School of Applied Science, the announcement of election of officers, etc.

Toronto

April 14—Joint meeting with Engg. Inst. of Canada at Hamilton, Ont.

April 28—Annual meeting.

Past Section Meetings

Akron

Electrical Welding of the Penstocks to Be Used at the Boulder Dam, by Mr. Trainer, Babcock & Wilcox Co. Feb. 14. Att. 140.

Boston

The Development of the New England Power System, by W. R. Bell and E. W. Dillard, both of the New England Pwr. Association. J. Allen Johnson, vice-pres., A.I.E.E., Buffalo, Niagara & Eastern Pwr. Corp., outlined the benefits of Institute membership. Feb. 14. Att. 125.

Chicago

The Common Neutral Distribution System, by N. C. Pearcy, Byllesby Engg. & Mgmt. Corp. Feb. 21. Att. 50.

Cincinnati

The Cincinnati Kilowatt Abroad, by E. D. Wood, Louisville Gas & Elec. Co. Feb. 9. Att. 65.

Cleveland

Maj. R. W. Pinger, Cleveland Ordnance Office, described the capture of his family and himself by Chinese bandits in 1923, and his varied experiences during his period of captivity before ransomed. Illus. Jan. 19. Att. 250.

Overseas Telephony, by F. A. Cowan, Am. Tel. & Tel. Co. Joint meeting with I.R.E. Feb. 16. Att. 235.

Columbus

Has the Engineer Worked Himself Out of a Job? by Dr. W. E. Wickenden, Case Sch. of Ap. Science. Feb. 24. Att. 175.

Denver

Lightning. Speakers: F. A. Eastom, E. E. Wyland, F. H. Brown, and L. M. Robertson. Dinner. Feb. 17. Att. 63.

Detroit Ann-Arbor

Hydroelectric Development and Its Present Status in the Industry, by E. M. Burd, Consumers Pwr. Co. Feb. 14. Att. 75.

Fort Wayne

Travel in the Orient, by Dr. W. K. Hatt, Purdue Univ. Feb. 20. Att. 130.

Indianapolis-Lafayette

The Inductive Coordination of Power and Telephone Lines, by E. R. Moore and E. G. Thoms, both of the Indiana Bell Tel. Co. Feb. 24. Att. 151.

Kansas City

The Requirements and Trend of Developments of Modern Air Conditioning, by S. R. Lewis, cons. engr. Institute Activities, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. Feb. 17. Att. 1010.

Lehigh Valley

Storms, Their Effect on and Method of Handling by Large Power and Communication Companies, by E. F. DeTurk, Metropolitan Edison Co. Illus. Feb. 10. Att. 85.

Los Angeles

Some Recent Developments in the Wire and Cable Industry, by D. M. Simmons, Genl. Cable Corp. Dinner. Feb. 14. Att. 103.

Louisville

A. M. Dudley, Westinghouse Elec. & Mfg. Co., gave a talk on recent developments in the electrical field. Jan. 6. Att. 100.

The Continuous Integraph, by J. C. Groves; The Rotary Voltmeter, by J. C. Morris; The Phase Advancer, by W. B. Watkins, Jr. Joint meeting with Univ. of Louisville Branch. Demonstrations. Feb. 17. Att. 41.

Lynn

The Story of the Mayas and the Ancient Civilization of Central America, by Dr. Alfred N. Tozzer, Harvard Univ. Dec. 7. Att. 800.

The Uses of Plastics in the Electrical Industry, by H. M. Richardson, Genl. Elec. Co.; Recent Developments in Insulated Cables for Transmission and Distribution of Electric Energy, by A. N. Weber, Lynn Gas & Elec. Co.; Present Day Trend in the Use of Insulated Wire, by I. H. Wilson, Genl. Elec. Co.; Some Insulation Problems of Very Small Wire Used for Instrument Purposes, by E. W. Clark, Genl. Elec. Co.; Cold Molded Plastics, by F. J. Groton, Genl. Elec. Co. Dec. 14. Att. 62.

A Naturalist in the Canadian Rockies, by Dan McCowan. Jan. 4. Att. 900.

Inspection trip to the Consolidated Elec. Lamp Co. Jan. 14. Att. 103.

The Dnieprostroy Power Plant of U.S.S.R., by C. C. Welchel, Genl. Elec. Co. and H. M. Zangler, constr. engr. Jan. 18. Att. 250.

Development and Growth of the Incandescent Lamp Industry, by Jasper Marsh; Use of Tungsten Lamp as a Filament, by D. H. Gardner, and Characteristics of Incandescent Lamps, by E. H. Raddin, all of the Consolidated Lamp Co. Feb. 1. Att. 150.

Memphis

Teletypewriter and Radio Broadcast Control, by E. A. Clement, Southern Bell Tel. & Tel. Co. Feb. 21. Att. 75.

Mexico

The Electric Arc, by E. Leonarz, Jr., Mexico Lt. & Pwr. Co. Feb. 23. Att. 41.

Minnesota

Joint meeting with University of Minnesota Branch. Awards of $15 and $10 were presented to Paul Erickson and John E. Hancock, respectively, for the presentation of the best student papers. Demonstration of television. Feb. 16. Att. 135.

Montana

Historical Development of Radio, by H. Dale Cline, Mountain States Tel. & Tel. Co.; Transpacific Radio Telephone Development, by R. B. Edwards, student; Radio Interference, by R. Hoffstatter, Montana Pwr. Co. Joint meeting with Montana State College Branch. Feb. 9. Att. 27.

Nebraska

Street Railway Operation, by L. G. Barnes. Omaha & Council Bluffs St. Ry. Co. Joint meeting with Engrs. Club of Omaha. Luncheon. Feb. 15. Att. 70.

Niagara Frontier

Television, by Dr. J. O. Perrine, Am. Tel. & Tel. Co. Dinner. Feb. 17. Att. 600.

Philadelphia

Synthetic Daylight, by R. D. Marley, Genl. Elec. Vapor Lamp Co.; Light in 1933, by G. Bertram Regar, Phila. Elec. Co. Feb. 13. Att. 268.

Pittsfield

Magic of the Ages, by Dr. Harlan Tarbell. Feb. 7. Att. 1400.

Applied Genetics, by Prof. H. D. Goodale, Mount Hope Farm. Annual prize for the year 1932, of $25, awarded to Harold L. Rorden for presentation of his paper entitled Solution of Circuits Subjected to Traveling Waves. Feb. 21. Att. 135.

Behind the Green Lights, by Capt. C. W. Willemse. Dinner. March 7. Att. 1100.

Portland

Inspection trip through all departments of the "Morning Oregonian" and Oregonian Broadcasting Station KGW. Feb. 10. Att. 145.

Industrial Applications of Vacuum Tubes, by E. S. Darlington, Genl. Elec. Co. Feb. 14. Att. 37.

Rochester

Equivalent Circuits of the Transformer, by C. F. Estwick. Joint meeting with I.R.E. and Rochester Engg. Soc. Feb. 9. Att. 22.

St. Louis

Progress Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. Demonstrations. Feb. 15. Att. 250.

Saskatchewan

Carrier Telephone System as Used in Saskatchewan, by W. L. Campkin, Dept. of Telephones; Lamps and Their Proper Use, by H. I. Nicholl. A. Townsend, Sask. Pwr. Comm., illustrated by means of a neon tube transformer the travel of an arc along a horn gap. Dec. 9. Att. 22.

Heat Balance in Steam Power Plants, by E. W. Butler, Bailey Meter Co. Jan. 26. Att. 34.

Schenectady

Technology and Social Change, by Prof. W. Rautenstrauch, Columbia Univ. Feb. 9. Att. 450.

The Planning and Conduct of Engineering Development, by M. A. Whiting, Genl. Elec. Co. Joint meeting with A.S.M.E. Feb. 23. Att. 125.

Seattle

Extending Our Frontiers Through Research and Engineering, by H. P. Charlesworth, pres., A.I.E.E., vice-pres., Bell Tel. Labs., Inc. Sept. 6. Att. 96.

J. M. Detwyler, DuPont Co., presented a paper covering many special features and problems surrounding the construction and operation of a plant for the manufacture of ammonia by the high pressure process. Oct. 18. Att. 32.

A New Development in a High Efficiency, Low Voltage Rare Gas Arc Lamp, by Prof. F. K. Kirsten, Univ. of Wash. Demonstrations. Nov. 15. Att. 78.

Economies of the Lumber Industry, by R. E. Sharp. Dec. 20. Att. 18.

Sharon

Explosions, Flames, and Their Propagation, by Dr. B. Lewis, Bureau of Mines Experiment Station. Film—"Turbine With the Solid Rotor." Feb. 21. Att. 180.

Springfield

Stroboscopic Light and Some of Its Uses, by Prof. H. E. Edgerton, Mass. Inst. of Tech. Feb. 13. Att. 650.

Toledo

Alternating Current Principles, by A. Hoefle, Toledo Edison Co.; Overseas Telephony, by F. A. Cowan, Am. Tel. & Tel. Co. Illus. Feb. 17. Att. 200.

Toronto

Television, by Dr. J. O. Perrine, Am. Tel. & Tel. Co. Joint meeting with I.R.E., Bell System Techn. Soc., and Mathematics and Physics Soc. of the Univ. of Toronto. Feb. 10. Att. 600.

Motor Applications and Some Problems in Engineering Research, by A. M. Dudley, Westinghouse Elec. & Mfg. Co. Feb. 23. Att. 92.

Washington

When the Earth Trembles, by Capt. N. H. Heck, U.S. Coast and Geodetic Survey. Illus. Dinner. Feb. 14. Att. 60.

Worcester

Electric Marine Propulsion, by F. V. Smith, Genl. Elec. Co. Feb. 14. Att. 35.

Past Branch Meetings

University of Alabama

Business meeting. Feb. 13. Att. 21.

Mercury Vapor Turbines, by O. Jezierny; The A.I.E.E. and What It Offers, by F. Livingston; Electricity Keeping Up With Crime, by W. K. Price, students. Feb. 27. Att. 25.

University of Arkansas

Thermo-Electricity, by R. Wagstaff; Fuseology, by H. Dover; System Stability, by H. Nelson, students. Feb. 2. Att. 23.

Rectifiers, by W. C. Warram; Obtaining Patents, by F. S. Grimmett; Annealing of Glass, by W. Hall, students. Feb. 16. Att. 24.

Electrical Characteristics of Transformers, by B. M. Haskins; Generator Cooling, by R. Watkins; Thermocouples, by R. Boyd, students. March 2. Att. 24.

University of British Columbia

Recent Developments in the Victoria Substation, by J. Hedley; Electrical Indicators, by W. Ling; Copper-Oxide Rectifiers, by H. C. Freedman, students. Feb. 9. Att. 13.

The Equipment of the S. S. Prince Rupert, by J. D. Mathews; Vacuum Tube Voltmeters, by R. Hilton; Oil-Filled Cables, by R. F. Hynd, students. Feb. 23. Att. 11.

Polytechnic Institute of Brooklyn

Applications of the Thyratron Tube, by Prof. Willis, Princeton Univ. Feb. 15. Att. 62.

California Institute of Technology

Moving pictures. Jan. 31. Att. 120.

Outlook of the Electrical Industry, by Prof. R. W. Sorensen, counselor. Feb. 28. Att. 35.

University of California

Executive committee meeting. Feb. 7. Att. 5.

Inspection trip to Fruitvale Steam Station of the Southern Pacific Railroad Co. Feb. 11. Att. 10.

The Economic Balance Between Steam and Hydroelectric Power, by F. M. Harris, Pacific Gas & Elec. Co. Feb. 16. Att. 42.

Clemson Agricultural College

Coal and Ash Handling, by C. H. Baer; Power House Auxiliaries, by T. H. Hewitt; Boilers and Turbines, by R. E. Holman; Alternators, by W. W. Dickson; Substation and Substation Equipment, by A. E. McCall; Transmission and Distribution, by W. F. Tribble, students. Joint meeting with A.S.M.E. branch. Feb. 7. Att. 69.

The Cathode Ray Oscillograph, by Prof. Tingley. Feb. 28. Att. 24.

Colorado Agricultural College

Deion Circuit Breakers, by Joseph Fry, student; Uses of Electricity in Industries, by H. Kahn, student. Feb. 13. Att. 14.

The Bureau of Standards, by Prof. J. Pinsky. Illus. Feb. 27. Att. 14.

University of Colorado

Engineering Economic Considerations, by R. C. Giese, Am. Tel. & Tel. Co. Jan. 25. Att. 40.

B. E. Moritz, explained the operation of and demonstrated his radio controlled yacht at the swimming pool in the gymnasium. Feb. 8. Att. 300.

Cooper Union

Inspection of the Columbia Broadcasting system transmitter of station WABC. Feb. 12. Att. 40.

University of Denver

Business meeting. Feb. 14. Att. 13.

Inspection of station KOA. Feb. 24. Att. 26.

Technocracy, by G. S. Conant, Amer. Technocratic League. Joint meeting with Engg. Assn. of Denver Univ. Feb. 26. Att. 84.

University of Detroit

Layout Work and Distribution of Power, by S. M. Dean, Detroit Edison Co. March 1. Att. 29.

Drexel Institute

Electrical Studies of Living Systems, by D. W. Bronk, Univ. of Pa. Hospital. Jan. 25. Att. 28.

I Dare You, by H. E. Harper, Pub. Serv. Coordinated Transport. Feb. 8. Att. 19.

Electrical Measuring Instruments, by J. P. Manypenny, Rubicon Instrument Co. Feb. 13. Att. 30.

Some of the Newest Developments in Portable Talking Motion Picture Equipment, by S. A. Quinby, R.C.A. Victor Co. March 8. Att. 28.

Duke University

Electric Railways, by K. T. Knight, student. Feb. 7. Att. 13.

Muscle Shoals, by R. P. Givens, student. Feb. 21. Att. 18.

Light, by Roy A. Palmer, Duke Pwr. Co. Feb. 27. Att. 148.

University of Florida

Modern Developments in the Electric Industry, by R. P. Smith, Westinghouse Elec. & Mfg. Co. Feb. 7. Att. 47.

The Value of Education in the College of Engineering, by Dean B. R. Van Leer. Feb. 27. Att. 60.

George Washington University

Election of officers: S. A. Woodzell, chmn.; J. F. Burns, vice-chmn.; J. F. Channel, secy.-treas. Dec. 7. Att. 20.

Radio in Aviation, by J. H. Dellinger, Bureau of Standards. Jan. 4. Att. 27.

The Teletypewriter, by G. L. Weller, Chesapeake & Potomac Tel. Co. Illus. Feb. 8. Att. 34.

Georgia School of Technology

Conditions and What to Do After Graduation, by Mr. Thibaut, Am. Tel. & Tel. Co. Jan. 18. Att. 76.

Iowa State College

Talks on the inspection trip to Chicago and Milwaukee by John Foster, Edward Morris, and Eugene Griffith, students. Dec. 14. Att. 20.

Discussion. Jan. 25. Att. 25.

Manufacture of Carbon Brushes, by Mr. Robinson, Natl. Carbon Co. Moving pictures. Feb. 2. Att. 125.

University of Iowa

Automatic Conversion of A-C to D-C for Railway Use, by Mr. Ewing. Feb. 8. Att. 28.

Election of officers: W. C. Davie, chmn.; M. J. Larsen, vice-chmn.; F. A. VanOsdol, secy. The History of Television, by Frank Palik, student. Feb. 15. Att. 32.

Films—"Behind the Lines" and "George Washington." Feb. 22. Att. 33.

Slow Discharge Tubes, by L. J. Saks; Illumination by Discharge Tubes, by I. Passman, students. March 1. Att. 30.

Kansas State College

Film—"The Lake of the Ozarks." Feb. 2. Att. 80.

University of Kansas

The Special Theory of Relativity, by Dr. J. D. Stranathan; Experiences in an Arizona Copper Mine, by E. B. Youngstrom; Relation of Various Branches of Engineering, by J. M. Kellogg. Feb. 23. Att. 45.

Lafayette College

Electroplating, by L. T. Johnson; Problems in Symmetrical Components, by F. H. Welsh, students. Feb. 17. Att. 25.

Lehigh University.

The Conowingo Power Plant, by N. E. Funk, Phila. Elec. Co. Illus. Feb. 24. Att. 45.

University of Louisville

Rotary Voltmeter, by Mr. Morris; Mechanical Integraph, by Mr. Groves, students. Feb. 10. Att. 14.

Marquette University

High Voltage Problems in High Tension Transmission, by Mr. Hatz, Milwaukee Elec. Ry. & Lt. Co. Jan. 12. Att. 17.

High Voltage Problems in Power Transformer Design, by Mr. Hill, Allis-Chalmers Mfg. Co. Feb. 9. Att. 15.

Michigan College of Mining and Technology

Electric Hoisting Machinery, by L. R. Messenger, student. Feb. 16. Att. 44.

The Manufacture and Application of Carbon Products, Principally Brushes and Commutators, by J. A. Robinson, Natl. Carbon Co. Motion pictures. March 2. Att. 70.

University of Michigan

The Employment Outlook for 1933, by Prof. A. D. Moore. Feb. 27. Att. 45.

Air Conditioning, by E. D. Harrington, Genl. Elec. Co. March 7. Att. 50.

Milwaukee School of Engineering

Characteristics of the Double Voltage Rectifier, by Mr. Lockhart and R. Fletcher; The St. Lawrence Waterway Project as It Stands Today, by D. J. Clark and J. W. Lefebvre; The Thyratron Tube as an Inverter, by E. Stachura, students. Feb. 8. Att. 63.

University of Minnesota

The Mercury Vapor Turbine, by P. Erickson; Electro-Chemistry, by J. Hancock; The Artificial Voice and Ear, by Sam Levy; Construction and Installation of a 115,000 Volt Submarine Cable, by A. Kupka, students. Paul Erickson and John Hancock awarded prizes of $25 and $15, respectively. Demonstration of television. Joint meeting with Minnesota Section. Feb. 16. Att. 135.

The Manufacture of Carbon Brushes, by L. A. Robinson, Natl. Carbon Co. Feb. 27. Att. 60.

Missouri School of Mines and Metallurgy

The Electrification of Mines, by Prof. Stienmesch. Films—"The Utah Copper Mines Electrified," "Induction Regulators," and "Automatic Substations." Feb. 8. Att. 24.

University of Missouri

Denotation of Line Troubles, by D. E. Wass, Southwestern Bell Tel. & Tel. Co. Feb. 8. Att. 15.

Montana State College

Electricity's Part in Open Cut Copper Mining, by Melvin Axelson; Floodlighting Public Buildings, by C. O. Bergland; Industrial Economics, by W. Flanze; Automatic Break-In for Radio Telephone, by R. V. Dean, students. Feb. 9. Att. 76.

A Three-Point Landing in the Aviation Market, by J. W. Gilmer; The Engineer and the Foreign Job, by M. Hilden; Lighting the Bottom of the Ocean, by D. A. Hyde; We Have Just Begun to Use Electric Lighting, by J. M. Kennedy; Synchronous Electric Time Service, by O. Lester; The Rio Grande Goes to Work, by F. Liquin, students. Feb. 16. Att. 79.

Ideas on Pepping Up Your Old Radio Set, by J. D. Mathews; The Battle of the Alchemists, by L. Peterson; Good Light for Famous Caves, by H. E. Murdock; The Telephone Goes to Sea, by G. W. Roberts; Some Interesting Sidelights on Steinmetz's Life, by D. C. Shevalier, students. Feb. 23. Att. 73.

Chain Broadcasts on One Wave Is Latest Radio Plan, by G. W. Misevic; A Self Stabalizing D.C. Welding Generator, by R. L. Spaulding; Gaseous Discharge Lamps, by D. Towne; Professional Ethics and Practices in Engineering, by E. Watts; Electricity and Animation, by J. A. White; students. March 2. Att. 75.

University of Nebraska

Lecture and demonstration by B. C. Burden, Lincoln Telephone Co. Feb. 15. Att. 335.

Newark College of Engineering

Cathode Ray Tubes, by Mr. Dumont. Joint meeting with Rutgers Univ. Branch. Jan. 30. Att. 65.

University of New Hampshire

Film—"Wildwood." Jan. 28. Att. 29.

Neutral by the Kick Method, by J. P. Kopecki; Is Voltage Reduced by Changing the Number of Lines Threading a Closed Circuit? by E. Priest. Feb. 4. Att. 32.

University of New Mexico

Radio Station Kob, by Mr. Remley, student. Dec. 14. Att. 12.

Displacement of the Steam Locomotive by the Electric Locomotive, by J. Luke, student. Explanation of the microphone by Mr. Remley, student. Jan. 10. Att. 15.

Induction of High Voltage, by Mr. Jones and Mr. Beahm, students; Radio Beams Used as a Guide in Commercial Flying, by Mr. Fish, student. Feb. 15. Att. 10.

Metz Beahm elected chairman. Feb. 16. Att. 9.

Automatic Block Signals Used on Railroads, by J. R. Walton, student. Feb. 28. Att. 9.

College of the City of New York

Business meeting. Feb. 16. Att. 30.

Discussion of future activities. Feb. 23. Att. 35.

Discussion of qualifications for student enrolment. March 2. Att. 18.

New York University

Problems of Vibration in Transmission Lines, by Wm. Fairnington; Short Wave Super-Heterodyne Reception, by C. Bielecki, students; The Art of After Dinner Speaking, by Prof. A. Haring. Feb. 10. Att. 23.

Talking Moving Pictures, by Wm. Sutton; Police Radio System, by E. Sarosy; Determination of the Variation of Electrical Conductivity With Mechanical Stress, by O. Heister, students. Feb. 24. Att. 20.

North Carolina State College

Thunder Clouds, by L. A. Densen, U.S. Weather Bureau. Feb. 21. Att. 32.

Accurate Time-Keeping Clocks, by N. York; Principles of the Electric Clock, by J. Bolen, students. March 7. Att. 35.

North Dakota State College

Rectifiers, by R. Acheson, student. Films—"Something About Switchboards," "Cedar Camps in Cloudland," and "Out of the Deep Woods of Dixie." Joint meeting with A.S.C.E. and A.S.M.E. branches. Feb. 24. Att. 47.

Business meeting. March 3. Att. 13.

University of North Dakota

Capacitator Voltage Regulation, by Wm. Barber; Radio Broadcasting Frequencies, by A. Stratmoen, students. Jan. 25. Att. 9.

Northeastern University

Transoceanic Telephony, by T. Cooper, New England Tel. & Tel. Co. Film—"Hello Europe." Feb. 24. Att. 40.

University of Notre Dame

Canadian Banking, by P. McCaffary; Mine Hoists, by C. Slatt, students. Rules and Regulations of an Airport, by Glen Borer, South Bend Airport. March 1. Att. 35.

Oklahoma A. & M. College

Parallel Operation of Steam and Hydro-electric Plants, by R. Gode; Mobile Color Lighting, by J. J. Mosshammer, students. Feb. 6. Att. 25.

University of Oklahoma

Discussion. Feb. 14. Att. 20.

Oregon State College

Vacuum Tubes and Their Industrial Applications, by E. S. Darlington, Genl. Elec. Co. Feb. 8. Att. 47.

Development of Arc Welding Equipment, by R. C. Cooper, Westinghouse Elec. & Mfg. Co. Feb. 16. Att. 22.

Traction Problems, by C. B. Short, Portland Traction Co. March 2. Att. 30.

Pennsylvania State College

Studies in Radiation and Insulation and Their Measuring Devices, by Mr. Queer, student. Jan. 12. Att. 33.

University of Porto Rico

Theory and Applications of the Oscillograph With Demonstrations, by Prof. G. F. Anton, counselor; Recreations in Mathematics, by O. Porrata Doria; The Michelson Experiment on the Velocity of Light, by R. Valls, students. Feb. 22. Att. 29.

Purdue University

Graphic Meters in Industry, by R. J. Kryter, Esterline-Angus Co. Feb. 9. Att. 70.

Induction Coordination, by J. H. Shaffer, student. March 1. Att. 40.

Rensselaer Polytechnic Institute

The Hydroelectric Development at Dnieprostroy, Russia, by C. C. Welchel, Genl. Elec. Co. Feb. 21. Att. 350.

Rhode Island State College

Routine Inspection in a Hydroelectric Station, by Amos Kent, student. March 2. Att. 20.

Rose Polytechnic Institute

Rotary Voltmeter, by A. J. Massa; The Use of Dry Batteries, by W. C. Bachelor, students. Feb. 9. Att. 31.

Electronic Music, by G. D. Reece; Rectifiers, by N. W. Liston, students. March 2. Att. 21.

Rutgers University

The Application of Higher Mathematics to Electrical Engineering Problems, by Mr. Kaplan, student. Feb. 21. Att. 21.

University of South Carolina

Business meeting. Feb. 10. Att. 21.

Organization and Work of the National Council of State Boards of Engineering Examiners, by T. Keith Legare, secy., So. Carolina State Board of Engg. Examiners. Feb. 27. Att. 76.

Discussion. March 6. Att. 18.

Southern Methodist University

Two illustrated talks presented. Feb. 15. Att. 22.

Stanford University

Engineering Developments, by A. W. Copley, vice-pres., A.I.E.E., Westinghouse Elec. & Mfg. Co. Jan. 26. Att. 27.

Wind Vibrations as Regards to Transmission Lines, by J. A. Koontz, Pacific Gas & Elec. Co. Illus. Feb. 16. Att. 18.

Syracuse University

High Voltage Circuit Breakers, by H. C. Wolfe; The Advantages of Railroad Electrification, by R. H. Thompson; The Demand Meter—Its Operation and Construction, by K. R. Stauss; The Making and Testing of Grounds, by K. B. Smith, students. Feb. 28. Att. 22.

University of Tennessee

Outside Telephone Plant, by Mr. Reese, Southern Bell Tel. Co. Feb. 1. Att. 18.

Amateur Radio, by Mr. Harrill, student. Feb. 15. Att. 15.

Tap Changing Under Load for Voltage Control, by J. Soyara; Early Development of the Photo-Cell, by Wm. Dean; World Fair Exhibits, by J. Steffner, students. March 1. Att. 10.

Texas A. & M. College

Motion pictures describing Dr. Millikan's experiments with the cosmic ray. Feb. 28. Att. 200.

University of Utah

Railway Practice on Electrified Lines of Germany, by Hans Dette. Jan. 24. Att. 24.

Circuit Breakers, by T. V. Anderson, student. Films—"The Making of Vacuum Tubes" and "Characteristics of Sound." Feb. 2. Att. 54.

Virginia Polytechnic Institute

The Electrical System for Modern Ocean Liners, by J. E. Kulm; The Stroboscope, by J. P. Gills, students. Feb. 16. Att. 38.

THE ELECTRIC LIGHT BULB, by E. H. Farley, student. Feb. 23. Att. 34.

RAILWAY COMMUNICATION SYSTEMS, by J. E. Homm; CIRCUIT BREAKER PROTECTION FOR INDUSTRIAL SERVICE, by R. W. McCorkle; TRAPPING ELECTRICITY THIEVES, by N. C. Moore; THE ART OF WINDING ARMATURES, by E. W. Seay; PROTECTIVE RELAYS, by E. W. Whitmer, students. March 2. Att. 20.

West Virginia University

CONSTANT CURRENT TRANSFORMERS, by F. Q. Brown; DEVELOPMENTS IN ELECTRICAL INDUSTRY IN 1932, by E. C. McMillan; INDUSTRIAL ECONOMICS, by E. Darrah; LIGHTNING EXPERIMENTS WITH WOODEN POLES, by C. L. Post; GENERAL DEVELOPMENT OF ELECTRICAL EQUIPMENT IN 1932, by J. Millard; TENSITIVITY OF NEWEST ELECTRICAL INSTRUMENTS, by G. F. Lefevre; TERRESTRIAL MAGNETISM, by F. E. Virgin, students. Feb. 7. Att. 26.

BROADCASTING STATION EQUIPMENT AND PRACTICE, by A. R. Simpson; AUTOMATICALLY OPERATED CAPACITOR EQUIPMENT FOR POWER FACTOR, by E. J. Williams; ELECTROLYTIC CONDENSER, by W. D. Hall; CONTROL OF INSTRUMENT SWITCHES, by K. C. Miller; AUXILIARY ELECTRIFICATION ON GRACE STEAMSHIP, by R. Caddock; COMPETITION IN ELECTRIC SUPPLY, by D. B. Shaffer; ELEMENTARY PROBLEMS IN TELEVISION RESEARCH, by J. G. Henderson; RECENT RAILWAY DEVELOPMENTS, by A. A. Dawson, students. Feb. 14. Att. 27.

RADIO TRANSMITTING ANTENNAS, by M. I. Hall; PROPERTIES AND USES OF INFRA-RED RAYS, by A. E. G. Bates; INDUSTRIAL STORAGE BATTERIES, by M. B. Tolley; POWER PACT, by C. V. Richmond; GRID CONTROLLED MERCURY ARC RECTIFIER, by R. H. Colborn; X-RAYING STEEL PLATES UP TO FOUR INCH THICKNESS, by L. W. Hall; NEW USES FOR VACUUM TUBE IN ELECTRON ARC OF X-RAY, by C. L. Anderson; BUYING ELECTRICITY AS AN ART, by W. L. Jacobs, students. Feb. 21. Att. 25.

POWER TRANSMISSION AND DISTRIBUTION IN THE U.S., by K. C. Miller; ELECTRICAL CONTROL FOR BOILER PRESSURES, by J. Millard; OIL BLAST BREAKERS OF MEDIUM CAPACITIES, by E. C. MacMillan; QUIET POWER HOUSES, by J. E. Darrah; TESTING OF WATTHOUR METERS, by L. P. Lovett; ELECTRICAL DEVELOPMENTS AT WEST POINT, by A. A. Dawson, students. Feb. 28. Att. 23.

Worcester Polytechnic Institute

INTERCONNECTION OF TRANSMISSION SYSTEMS, by J. A. Johnson, vice-pres., A.I.E.E., Buffalo, Niagara, and Eastern Pwr. Corp. Feb. 17. Att. 65.

Employment Notes

Of the Engineering Societies Employment Service

Men Available

Construction

GRAD. E. E., 30, 5 yr supervisory construction, design, estimating and field engg experience on super pwr. plants and substations; 4 yr industrial pwr. plant operation, elec construction and maintenance experience; ry. electrification construction experience. C-4428

Design and Development

DESIGN ENGR, B.S. in E.E. Yale, desires position in engg or teaching. Experience: 1 yr d-c test work, 4 yr development and application of outside plant apparatus in Bell Tel. Lab., also practical mech. work. Salary, location open. D-1305

SIGNALING ENGR, 37, married, Am., Worcester P.I., U. of Glasgow, Scotland; $1^1/_2$ yr submarine bldg. co., 2 yr Western Elec Co. installation, testing telephone swbds., 9 yr Bell Tel. Lab., design, lab. testing of automatic tel. switching systems. Now with co. producing high grade radio apparatus for special purposes. D-1942

E.E. GRAD., 28, married, desires position in design and development or teaching; 1 yr Westinghouse student course; 6 mos. Westinghouse design school; $1^1/_2$ yr design of fractional hp motors; $2^1/_2$ yr design of industrial motors. Available at once. Location, U.S. C-5051

ELEC DESIGN ENGR, univ. grad., 33, single. 8 yr experience on design of pwr and substations with utility and RR. companies. Last 3 yr asst. E.E. on design and field investigations in tropical So. Am. country. Willing to travel anywhere. Available immediately. C-4447

GRAD. ENGR, 28, single, desires position as distribution engr; 7 yr varied utility experience includes design and construction of distribution and transmission lines, rehabilitation of substations, standardization of distribution construction, estimates and cost records. Available immediately. D-1977

E.E. AND DESIGNER, transformers and resistance welding machy; 30, married. Grad. Canadian univ. Westinghouse test floor and student course. Westinghouse design school. Three yr designing power and distribution transformers, current limiting reactors; 1 yr design and development resistance welding machy. Some control and maintenance experience. Available immediately. C-9734

HARVARD GRAD. in E.E. and business administration desires design or teaching position. Married, 34, excellent references. Nearly 9 yr with large elec mfr. as designer on d-c apparatus, also pursuing graduate work and teaching course for graduate engrs. Available now. Invites correspondence. D-1986

E.E. GRAD., 30, 2 yr additional study in accounting, 5 yr Westinghouse experience on the elec and mech design and development of ventilating fans and fractional hp motors. Needs work at once. New England preferred. D-580

Executives

ENGR, qualified to direct all activities of utility operating or design divisions, 12 yr utility experience. Familiar with the necessary organization and equipment for economical operation, maintenance, development and construction. Location immaterial. Available at once. Married. C-4734

E.E., with administrative, development, inventive, design and personal contact experience; $6^1/_2$ yr with apparatus and systems of remote control of ry. switches and signal equipment; previous 1 yr in radio engg. Background in Westinghouse "Advanced Graduate Engineering School." Available immediately. D-1861

M.A.Sc., Univ. of Toronto. ENGR with considerable experience in lighting protection, dampening of mech. vibrations, inductive coordination, plant design, swbd. layout, surveying and motion picture photography with Ontario hydro. Experienced in handling men. Speaks, reads, writes French and Russian. Best references. Married. Available at once. C-7646

GRAD. E.E., 35, 9 yr utility experience, on tests of steam and elec equip. of industrial plants; 4 yr in sound, acoustics of bldgs., wiring, voice amplification, photoelectric cell and vacuum tube control circuits. Accustomed to directing the work of electricians and elec testers. Will go anywhere but prefers eastern U.S. B-6546

MGR. OR SUPT. Engr grad. 17 yr experience, construction, operating, mgmt. utility properties and industrial plants. Extensively Latin Am. Capable taking complete managerial charge. Desire if possible connection with utility co. either domestic or foreign. Familiar with Latin Am. requirements obtaining franchise, contracts. Speaks Spanish fluently. Married. C-761

LICENSED NEW JERSEY E.E., 35, 10 yr experience covering design, cost estimating and equipment specifications of pwr. plants, substations, transmission lines and industrial bldgs. Also 1 yr dumbwaiter testing and $^1/_2$ yr research work on cables. English and German languages. C-5473

E.E., E.E. deg.; 14 yr experience utilities covering valuation work, rate investigations, engg pwr. plants, substations, transmission lines, including estimates, specifications, design. Experience covers short circuit studies, stability analysis, investigations of systems for load conditions. Desires position, holding co., operating co. or engg firm. Available immediately. C-9570

GRAD. ENGR. Excellent 14 yr performance record industrial sales, sales promotion and advertising, in mfg., distribution and business paper publishing. Experienced directing men and details. Broad contacts. Excellent references; 37, married. Desires position mfr. or engg organization adjusting sales and promotional plans to present conditions. C-2850

UTILITY ENGR, 31, 10 yr elec utility experience principally with client companies of Elec Bond and Share, includes design, construction and operation of transmission and distribution systems, investigations and economic studies, reconstruction and development planning, annual budgets, accounting and general engg work affecting more economical operation and maintenance of facilities. B-6934

E.E., grad. Cornell Univ. '23, 33, married. Qualified to direct all activities of elec utility operating division. Familiar with organization, and equipment necessary for economical operation, maintenance, development and customers' service. C-5155

Instruction

INSTRUCTOR IN E.E., MATH., OR PHYS. E.E. GRAD., B.S. '27, M.S. '31, 1 yr advanced grad. study in above subjects. 2 yr transmission exp. with tel. co.; 2 yr research in E.E.; 1 yr and 1 summer term instruction in E.E. Available June 1933. Salary open, location immaterial. References available. D-837

MECH.-ELEC ENGR, 33, with 13 yr experience in mech. design and varied shop practice including four yr on the Cornell U. machine design faculty. Desires teaching or industrial engagement. Available on short notice. Salary open. D-122

B.S. '26, E.E. '27, Va. Poly. Inst., grad. work Union Col., Phi Kappa Phi, 33. One yr teaching fellow; 5 yr G. E. Co. including study courses, test course, a-c machy. design and central station engg. Desires position in engg, operating or teaching. D-1974

B.S. and E.E., Mich. State Col., 31, G.E. test, 4 yr practical experience with (manual, supervisory

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

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controlled, and automatic) pwr. substations, automatic ry. substations (rotary converter and rectifier) and (frame mounted, cell mounted, and metal clad) equipment. Willing to do engg, operating, or teaching. D-1597

Junior Engineers

E.E. GRAD., 24, 1932 Pratt Inst., 3 yr in d-c pwr. house, 4 yr on RR. signaling, 1 yr at sales. Location immaterial. D-1943

B.S. in E.E. 1929, U. of Mich., married, 30, 3 yr experience testing, experimenting of track circuit apparatus used in ry. signaling; made mathematical calculations on all types of track circuits. Desires research, ry. signaling or teaching position. Prepared to teach mathematics, physics, electromechanics. Available immediately. Salary and location open. D-1760

E.E. GRAD., U. of Wis., 1932, 23, single. Some experience in line and service work. Member of Eta Kappa Nu. Desires position affording experience and possible advancement. Salary and location secondary. Available immediately. D-1828

PURDUE GRAD., 1929, B.S. of E.E., 26, single, six mos. with radio mfr., 1 yr extensive utility training course, six mos. in engg office. References. Desires employment with utility or mfr. D-1801

E.E. GRAD., Wash. State '32, Japanese, single. Earned way through college. Graduated with highest honor. Member Tau Beta Pi, Phi Kappa Phi and Pi Mu Epsilon. Desires E.E. work. Speak and write Japanese freely. Good college reference. Location immaterial. D-1958

B.S. in E.E. '31 in Washington State Col. Getting B.A. in education in June. Interested in teaching engg subjects, but would be glad of opportunity to get anything in engg field. Good references. Member of Tau Beta Pi and the Phi Kappa Phi. D-1963

E.E. GRAD., 1931, 29, single. One yr practical experience with Bell System and 2 yr on Westinghouse motor test floor before entering college; additional 1½ yr on test floor since graduation; 1 yr tech. school after high school. Desires motor engg. Location immaterial. D-1964

U. OF WIS., 1932 GRAD., B.S. E.E., 24, single. Member of Eta Kappa Nu. Radio or telephone work preferred. Experience: swbd. installation, meter testing, and station operation. References available. Location and salary secondary. Available immediately. D-1975

E.E., 26, grad. Worcester Poly. Inst., 4½ yr experience with large utility, handling electrolysis testing of cables in eastern part of country. Familiar with methods of correcting electrolytic action on all underground structures. Good knowledge of underground cable standards and specifications. Working knowledge of elec traction systems. D-1980

B.S. in E.E., U. of Kansas, 1930, 26, single, desires engg survey or editorial work; 2½ yr experience compiling and editing engg development reports for Bell Tel. Lab., Inc. Western U.S. preferred. D-2002

E.E. GRAD., Purdue, 1929, single, 26, 2 yr experience in valuation of substation, steam plant, gas and water equipment for utility, 1 yr experience as junior elec engr with large oil refinery. Available March 15, present location, Pacific Coast, but will consider anything. D-2000

E.E. GRAD., B.S. 1932; E.E. 1933; single, 21, honor student, Phi Beta Kappa. Grad. work in transmission. Desires work in E.E. field with possibility of advancement. Experience main consideration. Available at once. D-1993

Maintenance and Operation

RELAY ENGR, B.S. E.E. Tau Beta Pi, 35, single. Ten yr with Westinghouse on control, protective relays for substations, transmission lines, locomotives. All phases, preliminary design to field service; specifications, reports, articles. Calculating machines, boards. Expert stenographer. Prefer utility operating protection development. Design for manufacture second. Location domestic. Salary commensurate. D-1940

ELEC CONTROL AND MAINTENANCE ENGR, 34, single, grad. E.E., 12 yr elec maintenance, large Eastern steel plant charge of all motor control problems, 1½ yr in Russia on new steel plant layout work as member of American firm. Desires position with elec mfg. or industrial organization. Excellent references. Available immediately. D-1953

Research

E.E., 1928 grad., married, desires position requiring elec research or development work. Two yr experience installing, repairing, and teaching the operation of X-ray and physical therapy equipment; 1 yr in the research lab. of R.C.A. Victor Co. on speakers, auditorium equipment, and photophone equipment. Location immaterial. C-4220.

E.E., young, formerly in charge of field office for Federal Radio Commission, having field intensity, survey, frequency monitoring, inspection, investigation, research and correlated experience. Desires connection in field of electronic endeavor. Open minded as to salary and location. Available now. D-1804

Sales

SPECIALIST in heat transfer equipment. E.E. background. Executive sales work desired. Would consider branch territory assignment. D-653

Membership

Recommended for Transfer

The board of examiners, at its meeting of March 14, 1933, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Fellow

Armbrust, George M., asst. E. E., Commonwealth Edison Co., Chicago, Ill.
Bowles, Edward L., asso. prof. of elec. communications, Mass. Inst. of Tech., Cambridge, Mass.
Craft, Francis M., chief engr., Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Dreher, Carl, director of sound; chmn., tech. com., RKO Studios, Los Angeles, Calif.
Harvey, Harold G., engg. mgr., Southeastern dist., Westinghouse Elec. & Mfg. Co., Atlanta, Ga.
Sims, Wm. F., E.E., Commonwealth Edison Co., Chicago, Ill.

To Grade of Member

Garretson, Harry D., chief engr., Waite & Bartlett Mfg. Co., L. I. City, N. Y.
Herrick, George H., E.E., Fairbanks, Morse & Co., Beloit, Wis.
Lassen, Eivind U., supervising engr., Cutler-Hammer, Inc., Milwaukee, Wis.
Leinbach, John R., E.E., Lehigh Portland Cement Co., Allentown, Pa.
Mills, Neil, division plant telegraph engr., Am. Tel. & Tel. Co., Denver, Colo.
Smith, John M., E.E., Gen. Elec. Co., E. Cleveland, Ohio

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the acting national secretary before April 30, 1933.

Austin, T. M., Iowa St. Col., Ames.
Anderson, N. A., 1 Gunnarson Rd., Worcester, Mass.
Bachli, W. K., 20 Hoxsey St., Williamstown, Mass.
Back, L. B., 2521 Brookfield Ave., Baltimore, Md.
Baker, J. H., 135 Centre St., Kingston, Ont., Can.
Baker, R. F., Tonawanda High School, Tonawanda, N. Y.
Becker, D. J., 731 E. 20th St., Baltimore, Md.
Beckman, C. A., Detroit Sulphite Pulp & Paper Co., Mich.
Bell, C. E., 120 E. 2nd St., Trinidad, Colo.
Bergey, J. A., Koppers Rainey Coke Co., Conshohocken, Pa.
Bertolett, A. D., S.S. Isaac T. Mann, Pocahontos S.S. Co., Boston, Mass.
Bisordi, C. D., Box 817, Livermore, Calif.
Bobo, P. O., Oklahoma State Highway Dept., Oklahoma City.
Bowler, G. E., Metropolitan Water Dist., Beaumont, Calif.
Boyer, J. C., Jr., E. Wilson Co., Lake Village, Ark.
Brandt, D. F., 1748 N. 62nd St., Philadelphia, Pa.
Braun, C. A., Bklyn. Edison Co., Bklyn., N. Y.
Burfield, C. E., 395 Florence Ave., Newark, N. J.
Byam, L. A., 465 Stevens St., Lowell, Mass.
Caldwell, W. S., Jr., Univ. of Pa., Philadelphia, Pa.
Carew, W. J., 107 Pennsylvania Ave., Newark, N. J.
Carlton, E. W., Elec. Res. Prod., Inc., Chicago, Ill.
Chandler, L., Jr., Mass. Inst. of Tech., Cambridge.
Child, D. E., 106 S. Main St., Putnam, Conn.
Chiofalo, J., 203 Graham Ave., Bklyn., N. Y.
Clapp, R. G., P. O. Box 222, Rutledge, Pa.
Cosgriff, C. J., Cohocton, N. Y.
Craig, H. M., Bell Tel. Lab., Inc., Omaha, Neb.
Criss, G. B., 1224 44th St., Bklyn., N. Y.
Cullison, F. H., 107 N. Sycamore Iola, Kas.
Cuthbertson, L., R. F. D. 2, Box 153, Girard, Kas.
Daniels, G. A., Box 42, San Luis Rey, Calif.
Davis, R. K., 46 Webster St., Fort Plain, N. Y.
Deerhake, F. M., 1003 4th St. W., Huntington, W. Va.
DeRitter, W., 464 E. 22nd St., Paterson, N. J.
Dillon, K. L., Am. Cast Iron Pipe Co., Birmingham Ala.
Dinnar, L. C., 2001 University Ave., N. Y. City.
Dobson, C. J., Box 424, Carson City, Nev.
Dockstder, L. E., Elmira Lt., Heat & Pwr. Co., Elmira Heights, N. Y.
Dombart, W. F., Gulf Production Co., Pittsburgh, Pa.
Early, R. L., 3404 College Ave., Indianapolis, Ind.
Edington, N. W., Edington Sign Serv., W. Lafayette, Ind.
Ellis, V., 359 Wilden Pl., S. Orange, N. J.
Elsey, P. J., 422 Park St., Salt Lake City, Utah.
Fairnington, W. J., 103 Chase Ave., Yonkers, N. Y.
Fehr, A. H., 1413 Elati St., Denver, Colo.
Ferrier, G. W., Box 332, Perth, Ontario, Can.
Finch, H. D., Radio Serv., E. Stanwood, Wash.
Fleming, D. M., Pratt Inst., Bklyn., N. Y.
Garrett, S. N., Cumberland, Va.
Goddin, A. H., Grasselli Chem. Co., Wooster, O.
Grebe, H. L., 115 Scheerer Ave., Newark, N. J.
Griffith, L. F., (Member), 123 W. 57 St., N. Y. City.
Guth, H. H., Va. Elec. & Pwr. Co., Hopewell.
Haas, P. A., Kansas City Municipal Plant, Kansas City, Kas.
Hall, J. B., 119 N. Glendale Ave., Glendale, Calif.
Hallahan, W. J., Bklyn. Edison Co., Inc., Bklyn., N. Y.
Hatch, M. F., 617 E. 31st Ave., Spokane, Wash.
Hatcher, G. T., Pa. Water & Pwr. Co., Quarryville.
Heacock, E. R., Tuscola, Ill.
Headapohl, V. F., Am. Tel. & Tel. Co., N. Y. City.
Hervey, G. E., III, 345 P. O. Bldg., Baltimore, Md.
Holdcroft, F. G., 3112 No. 58th St., Omaha, Neb.
Jackson, R. C., 1310 W. 40 St., Kansas City, Mo.
Johnson, W. M., Iowa St. Col., Ames.
Kaderabek, K. E., 712 E. Wells St., Milwaukee, Wis.
Kaiser, W. L., 1504 Warwood Ave., Wheeling, W. Va.
Kelly, T. J., Natl. Dist. Tel. Co., N. Y. City.
Leggett, A. B., U. S. S. Houston, c/o Postmaster, Seattle, Wash.
Lennberg, F. A., Jr., 330 E. 27th St., Erie, Pa.
Lockhardt, C. M., 690 Bexley Rd., W. Lafayette, Ind.
Loraff, H. A., 1020 E. Pleasant St., Milwaukee, Wis.
Malan, S. F., 2939 N. Lawndale Ave., Chicago, Ill.
Manion, W. J., Am. Tel. & Tel. Co., N. Y. City.
McDonald, W. W., Britannia Mining & Smelting Co., Ltd., Britannia Beach, B. C.
McKinney, H. R., 2601 Durant Ave., Berkeley, Calif.
Mengel, A. R., 119 Morwood Ave., West Lawn, Pa.
Millar, J. G., San Antonio Pub. Serv. Co., Texas.
Miller, E. W., Pub. Serv. Co. of No. Ill., Evanston, Ill.
Milliken, F. H., Bowerston, O.
Moff, C. A., Cambridge Elec. Lt. Co., Mass.
Moore, A. H., Purdue Univ., W. Lafayette, Ind.
Morey, W. H., Bryant Road, Cummington, Mass.
Morse, W. H., Bellair Driveway, Dobbs Ferry, N. Y.
Nash, C. C., Jr., Texas A. & M. College, Dallas.
Neubauer, R. A., 65 Driscoll Ave., Rockville Centre, N. Y.
Nishiyama, W. S., 1333 E. 8 South St., Salt Lake City, Utah.
Noek, C. C., Boaz, Ala.
Nunley, C. T., Jr., Box 72 Gallatin, Tenn.
Odenheim, J. H., Philco Radio Co., Phila., Pa.
Olson, P. R., 73 Jerome Ave., Auburn, Mass.
Parachini, L. F., D. L. Miller, Inc., Hillside, N. J.
Peck, R. H., 12212 Locke Ave., Cleveland, O.
Peddie, L. W., 63 Bwdy. Ave., Toronto 12, Ont., Can.
Price, D. D., 246 Aurora Ave., Bonnabel Pl., New Orleans, La.
Rabow, A. N., Solar Mfg. Co., N. Y. City.
Rainey, W., Phila. Genl. Hospital, Pa.
Richardson, C. A., Bklyn. Edison Co., Bklyn., N. Y.
Riesenkonig, H. F., Lithoprint Co. of New York, Inc., N. Y. City.
Rockwell, D. T., 131 Church St., Saratoga Springs, N. Y.
Ross, C. A., 447 E. 8 St., Moscow, Idaho.
Ryan, C. J., 2071 Oakwood Ave., Grand Rapids, Mich.
Schad, L. W., Westinghouse Research Lab., East Pittsburgh, Pa.
Schiefner, R., Lawrence, Mich.
Schinke, M. J., 9632 Parnell Ave., Chicago, Ill.
Schultz, C. L., Radio Serv., Brazil, Ind.
Schumann, A. H., 2730 N. Central Park Ave., Chicago, Ill.
Scott, B. B., Jr., Carnegie Inst. of Tech., Pittsburgh, Pa.

Shafer, G. A., 103 N. Elmwood Ave., Topeka, Kans.
Simpson, J. A., Am. Tel. & Tel. Co., N. Y. City.
Smith, T. R., Midwest Lab., Newton, Ia.
Somerville, E. W., 439 Main St., Clinton, Mass.
Sphar, C. H., 790 Oak St., San Francisco, Calif.
Staklinski, F. J., 278 Ryerson St., Bklyn., N. Y.
Stern, H. C., 4410 Calvert St., Lincoln, Neb.
Stiles, W. B., Genl. Del., Ames, Ia.
Stone, L. P., 40 Page St., Keene, N. H.
Sundstedt, A., 1510 N. Marshall St., Milwaukee, Wis.
Temple, L. W., Jr., 4534 N. Colorado St., Phila., Pa.
Thein, L. P., St. Mary's Univ., San Antonio, Tex.
Thompson, E., 2 Webster St., Malden, Mass.
Trotter, J. M., 4220 West End Ave., Chicago, Ill.
Turner, E. A., Jr., Humble Oil & Refining Co., Houston, Tex.
Walker, S. A., Dallas Pwr. & Lt. Co., Dallas, Tex.
Wappler, F. C. (Fellow), Comprex Oscillator Corp., N. Y. City.
Weaver, W. F., The Treasure Chest, Asheville, N. C.
Webb, L. W., Jr., Norfolk Div. of Va. Poly. Inst., Norfolk, Va.
Wells, D. H., 67 Vine St., North East, Pa.
Whitehead, J. E., Pa. RR. Co., N. Y. City.
Whitehead, L. E., Commonwealth Edison Co., Chicago, Ill.
Whiteman, R. L., Standard Oil Co., Miami, Fla.
Whittaker, E. W., 6112 Keystone St., Phila., Pa.
Yeakle, R. B., Whitemarch, Montg. Co., Pa.
Yunker, P. J., 424 Union St., Hackensack, N. J.
134 Domestic

Foreign

Akre, E. O., Mexican Lt. & Pr. Co., Mexico City, D. F., Mexico.
Betz, B. R., Jr., Panama Canal Concrete Testing Lab., Balboa Heights, Canal Zone.
Cuneo, E. W., Calle San Nicolas No. 24, Pergamino, Argentina, S. A.
Dumit, E. J., Am. Univ., Beirut, Syria.
Hailey, G. (Member), The Hongkong Elec.Co., Ltd., Hongkong, China.
Innocencio, D., La Carlota Sugar Central La Carlota Occidental Negros, Philippine Islands.
Mathur, B. S., Marwar Elec. Supply Co., Jodhpur (Rajputana) India.
Mirikin, I., Palestine Elec. Co., Ltd., Tel.-Aviv, Palestine.
Miyata, H., 817 Sheridan St., Honolulu, Hawaii.
Moorman, H. R., c/o Lage Petroleum Corp., Maracaibo, Venezuela, S. A.
Prache, P. M., Forges et Ateliers de Constructions Electriques Jeumont, Nord, France.
Simonsen, O., Box 466, Ancon, Canal Zone.
Singh, L. (Member), Punjab Pub. Wks. Dept., Batala City, Punjab, India.
Skerrett, H. R., 10 Hernandez St., Santurce, Puerto Rico.
Varma, R. D., c/o Siemens-Schuckertwerke, A. U. 2 Berlin, Siemensstadt, Germany.
Webber, W., Cia Mexico de Petrolso El Aguila, Mexico, D. F., Mexico.
Widgery, R. G. (Member), Kingston-upon-Thames Corp., Kingston-on-Thames, Surrey, Eng.
17 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute records. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Averbach, Jacob E., 1242 Mich. Theatre Bldg., Detroit, Mich.
Barnes, James P., 29 Cardinal Ave., Albany, N. Y.
Bell, E. DeWitt, 335 River Road, Bogota, N. J.
Brobson, John F., Detroit Daily Mirror, Detroit, Mich.
Carroll, J. G., 1537 Walnut St., Kansas City, Mo.
Davis, George P., 184 S. Grace Ave., Lombard, Ill.
Feldheim, Fred S., Switchgear Engg. Dept., Genl. Elec. Co., Phila., Pa.
Hardey, John Ernest, Box 551, Wellington, N. Z.
Jansson, E. O., 53 Ashland St., West Lynn, Mass.
Johns, Francis J., Westinghouse Club, Wilkinsburg, Pa.
Kane, Martin P., Box 99, E. Pittsburgh, Pa.
Peck, Theodore A., Box 117, Norwood, Mass.
Schlechter, A. H., 103 W. 9th St., Apt. 6, Oklahoma City, Okla.
Smith, Frederic V. M., Texlite Elec Sign Co., 4112 Commerce St., Dallas, Texas.
Talbot, H. L., 3562 Lorne Ave., Montreal, Que., Can.
Tinkey, Otto G., 1401 Albarado Terrace, Los Angeles, Calif.
Tripp, William A., Stone & Webster Engg. Corp., 49 Federal St., Boston, Mass.
Vincent, Henry L., E. 916—19th St., Spokane, Wash.
Weber, Joe, 705—18th St., N. W., Washington, D. C.
Wiles, Warner M., c/o Intl. Ry. Co., 855 Main St., Buffalo, N. Y.

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, during February are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface or text of the book in question.

STRUCTURAL MECHANICS. By H. W. Hayward, A. F. Holmes, and R. G. Adams. N. Y. and Lond., McGraw-Hill Book Co., 1932. 182 p., illus., 9x6 in., cloth, $2.25. Prepared for students in the Lowell Institute free evening school and intended to enable them to follow succeeding courses in structural design and machine design, or as preparation for more advanced courses in structural mechanics. It is a complete revision of an earlier work. The book is intended for those familiar with the calculus, which is used freely.

WAVE MECHANICS, Elementary Theory. By J. Frenkel. Oxford, Eng., Clarendon Press. (Gift of Oxford Univ. Press, N. Y.) 1932. 278 p., diagrs., 10x7 in., cloth, 20s. First volume of a treatise in 3 volumes, each complete in itself, intended to replace the author's "Einfuehrung in die Wellenmechanik"; it is, however, practically a new work. The present volume gives a general survey of the whole subject of wave mechanics and of the new quantum statistics connected with it and also discusses the application of the quantum statistics to the electron theory of metals.

OIL ENGINE TRACTION (Howard Lectures). By A. E. L. Chorlton. Lond., Royal Soc. of Arts, 1932. 79 p., illus., 10x7 in., paper, 3s.—Contains a series of 4 lectures delivered before the Society in March 1932. The first lecture discusses the applications that have been made of the oil engine to railway and road traction, and the results obtained. The second describes the development of the oil engine for traction, and the remaining 2 describe various electric, gear and fluid transmissions for oil locomotives.

POWER PLANT ENGINEERING and DESIGN. By F. T. Morse. N. Y., D. Van Nostrand Co., 1932. 813 p., illus., 9x6 in., cloth, $6.50.—The aim of this book is to present in 1 volume a study of electric generating stations, including public service, industrial and institutional plants. Attention is paid to both mechanical and electrical features and to economic factors. Steam plants are given most attention, but hydroelectric and diesel-engine plants are also considered.

VIBRATION PREVENTION in ENGINEERING. By A. L. Kimball. N. Y., John Wiley & Sons, 1932. 145 p., illus., 9x6 in., cloth, $2.50.—The subject is presented concisely, yet with sufficient comprehensiveness to handle effectively any of the problems that usually arise. The book is based upon the direct experience of the author in the engineering work of the General Electric Company and represents a series of lectures recently delivered at the Harvard Engineering School.

ANALYTICAL MECHANICS for ENGINEERS. By F. B. Seely and N. E. Ensign. N. Y., John Wiley & Sons, 1933. 414 p., illus., 9x6 in., cloth, $3.75.—Presents those principles of mechanics essential for engineers. Aims to develop them from common experience, apply them to practical problems, and emphasize their physical interpretation. New edition, revised and reset.

APPLIED X-RAYS. By G. L. Clark. 2 ed. N. Y. & Lond., McGraw-Hill Book Co., 1932. 470 p., illus., 9x6 in., cloth, $5.00.—Intended for the industrial executive who wishes to know what X-rays are, how they may be used, and the ways in which they can be applied to practical industrial problems. Discusses general physics and applications of x-radiation, and the analysis of the ultimate structures of materials. New edition, entirely rewritten.

ELECTRIC WIRING FOR LIGHTING AND POWER INSTALLATIONS. By A. L. Cook. 3 ed. N. Y., John Wiley & Sons, 1933. 463 p., illus., 8x5 in., cloth, $3.00.—A guide to modern practice in the design and installation of interior wiring and systems, intended especially for superintendents and operators of installations and for wiremen, but also of interest to students and to architects. Simple rules are given for determining the size and arrangement of lighting units and for estimating the kinds of service. Rewritten to conform to recent changes in practice and the N. E. C.

HEAT TRANSMISSION. By W. H. McAdams. N. Y. & Lond., McGraw-Hill Book Co., 1933. 383 p., illus., 9x6 in., cloth, $5.00.—Prepared under auspices of the heat transmission committee of the National Research Council. Principles of heat transmission by conduction, radiation, and convection are presented. The literature and many unpublished data have been critically examined and correlated for the important cases of heat transfer, and the results presented as formulas and graphs for use in engineering design. Bibliography of over 400 items.

HYDRODYNAMICS. By Sir H. Lamb. 6 ed., Cambridge (Eng.) Univ. Press; Macmillan Co., N. Y., 1932. 738 p., illus., 11x7 in., cloth, $12.00.—New edition of a classic treatise. Unchanged in plan and arrangement but revised to include much new matter.

NEW INTERNATIONAL ASSOCIATION for the TESTING OF MATERIALS. FIRST COMMUNICATIONS. 1930. 4 vols. Groups A-D. Zurich, Switzerland, NIATM, 1930. Illus., 11x8 in., cloth, $10.00.—Brief reports on the testing of materials, designed to exhibit the present state of knowledge. The volumes deal respectively with metals, inorganic non-metallic materials, organic materials, and questions of general importance. The reports, by various authorities, are printed in English, French, or German, with English summaries in all cases.

PRACTICAL ELECTRICITY. By T. Croft. 3 ed.. N. Y. & Lond., McGraw-Hill Book Co., 1933. 674 p., illus., 9x6 in., lea., $3.00.—New edition enlarged by adding a section on vacuum tubes and their uses. The section on matter has been revised.

PRAKTISCHE GROSSZAHL-FORSCHUNG. By K. Daeves. Berlin, VDI-Verlag, 1933. 132 p., illus., 8x6 in., cloth, 7.20 rm.—The use of statistical analysis for the control of quality and waste in manufacturing is systematically presented in this work, intended for manufacturers and engineers. Simple, practical methods are described for collecting and analyzing data and formulating rules for quality control. The methods are almost entirely graphical.

RADIO ENGINEERING HANDBOOK. By K. Henney. N. Y. & Lond., McGraw-Hill Book Co., 1933. 583 p., illus., 7x5 in., lea., $5.00.—A compact reference book for radio engineers, the joint work of a number of specialists. Practice, rather than theory, is emphasized. All phases of the subject are treated.

SOUND-PICTURE RECORDING and PROJECTION. By K. M. MacIlvain. Scranton, Pa., Intl. Textbook Co., 1931. 55 p., illus., 8x5 in., cloth, $1.35.—A brief elementary exposition of methods and machines for making and showing sound pictures.

STANDARD HANDBOOK for ELECTRICAL ENGINEERS. Edit. by F. F. Fowle. 6th ed. N. Y. & Lond., McGraw-Hill Book Co., 1933. 2816 p., illus., 7x5 in., lea., $7.00.—This edition of this well-known handbook retains the plan and general character of earlier issues, but the test has been thoroughly revised, 600 pages have been added, and 3/4 of the subject matter is said to be new. The number of contributors has been greatly increased and several new sections added.

Engineering Societies Library

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MAINTAINED as a public reference library of engineering and the allied sciences, this library is a cooperative activity of the national societies of civil, electrical, mechanical, and mining engineers.

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Industrial Notes

Square D Elects Officers.—At its annual meeting March 15, the board of directors of the Square D Company, Detroit, Milwaukee, and Peru, Indiana, elected F. W. Magin, formerly executive vice-president, to the office of president. T. J. Kauffman was elected chairman of the board. H. S. Morgan, of Detroit, was elected secretary-treasurer. Mr. Morgan was formerly a member of the board of directors and retains his position on the board. J. H. Pengilly, of Los Angeles, L. W. Mercer, Vernon Brown, and Carlton M. Higbie were elected vice-presidents. Mr. Magin was formerly active head of the industrial controller division at Milwaukee.

"Off-Peak" Refrigeration Scheme Developed.—Announcement has been made by Glenn Muffly, with whom is associated J. G. DeRemer (A'07, M'13, A.I.E.E.) and G. W. Dunham, all of New York, of a scheme of off-peak refrigeration which appears attractive to power companies desiring to encourage this type of load. The refrigeration plan, developed for household use, consists of the use of a eutectic solution and special control equipment for maintaining constant refrigeration temperature throughout the day, power being taken only during off-peak hours as determined by a clock mechanism. The group holding the patents on the solution and control equipment does not intend to manufacture refrigerators, but to license a few leading manufacturers to produce these refrigerators. Merchandising plans proposed include, for apartment houses, etc., a separate meter and low, off-peak rate; and for household use a credit by the power company on the first cost of the refrigerator.

General Radio to Investigate Possibilities of Medical Field.—According to a recent announcement, the General Radio Company for some time has been interested in the possibilities of electrical measurements as applied to the medical and biophysics fields. Although some of its apparatus has been built specifically for these fields, its work therein has not been extensive. Arrangements have been completed with the Massachusetts Institute of Technology whereby J. Warren Horton (A'20, F'28, A.I.E.E.) who has been chief engineer of the General Radio Company, becomes a member of the research staff of M.I.T. to investigate this very broad problem. It is not contemplated that there will be any immediate development of apparatus, but that for the present the broadest aspects of the problem will be investigated under Mr. Horton's direction. Although Mr. Horton will be at the Institute of Technology, he will retain his association with the General Radio Company and will serve in the capacity of consulting engineer not only on problems pertaining to the medical research, but on those problems which he was directing as chief engineer of the company.

New Safety Switch.—The Electric Controller & Mfg. Co., Cleveland, announces a new type "A" safety switch. Although designed for severe duty encountered in mill service, these switches are of extremely compact construction; the overall dimensions are small, permitting minimum mounting space. Furthermore, they are enclosed in boxes having a handsome finish, making them applicable where good appearance is important. The switches are quick make and quick break—double break, semi-floating V-blades (movable contacts) engage and open rapidly; they cannot be partially opened or closed. The fuse door of the switches is interlocked with the operating handle, and the fuse cannot be reached except when the switch is opened. They are convertible from larger to smaller sizes by changing fuse clips and moving the fuse block to the proper threaded holes.

Heating Cable Used for Many Purposes.—Electric soil heating cable, announced some time ago by the General Electric Company, has been applied to a variety of purposes. The flexible lead-sheathed cable is used not only for hot beds, cold frames, propagating benches, germinators and other agricultural purposes, but also in many unexpected applications where a uniform distribution of a small amount of heat over a large area is desired. Aquaria and lily ponds containing delicate tropical fish or rare plants that cannot withstand chilled water have been protected with lengths of the cable. Floors in buildings are being kept warm and dry. Other installations of the cable are supplying low heat to liquid products in pipe lines in factories. Industrial applications have also included immersion heating for miscellaneous storage, treating and manufacturing processes in such varied places as glass, chemical, and soap factories. Incubators and brooders are being kept warm with the cable, thermostatically controlled; and down spouts and gutters of homes and other buildings are kept from being ice-clogged.

Trade Literature

Ash Handling Equipment.—Bulletin, 14 pp. Describes the Hydro-Ash system of sluicing ashes for power plants. Hydro-Ash Corp., 115 So. Dearborn St., Chicago, Ill.

Window Lighting Units.—Bulletin R24, 4 pp. Describes a new, easily adjustable show window lighting unit; also adaptable to other uses. The Wadsworth Electric Mfg. Co., Covington, Ky.

Electric Furnaces.—Bulletin 280, 8 pp. Describes "Falcon" continuous electric furnaces for hardening, tempering and annealing strip metal and wire products. H. O. Swoboda, Inc., 3530 Forbes St., Pittsburgh, Pa.

Variable Speed Motor.—Bulletin, 4 pp. Describes the U.S. "Varidrive" Motor, consisting of a squirrel cage motor and a variable speed differential whereby any speed over a wide range is instantly available through a simple control while the driven machine is in operation. U.S. Electrical Mfg. Co., Los Angeles, Calif.

Surge Proof Transformers.—Bulletin, 8 pp. Describes Ferranti surge proof transformers, which are protected by surge absorbers. Experiences of users are quoted in the illustrated bulletin. Ferranti, Inc., 130 West 42nd St., New York.

Floodlighting Equipment.—Catalog, 219-C, 52 pp. Describes Westinghouse floodlighting equipment. Many recent and unusual floodlighting installations are illustrated, together with a photograph and description of every type of floodlighting equipment manufactured by the Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Motor Reduction Units.—Bulletin 1164, 4 pp. Describes the Allis-Chalmers motor reduction unit—a compact, self-contained speed reducer that provides low speed drives without sacrificing the inherent advantages of the separate motor and speed reducer construction. The units can be furnished with any type of standard motor. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Commercial Cooking Manual.—Bulletin S. P. 1957, 64 pp., entitled "Cooking and Baking by Electricity," described as the most complete publication of its kind yet printed. In the preparation of this booklet, every effort has been made to secure the facts as to the real economic value of electric equipment and the comparative operation of fuel fired equipment. Westinghouse Elec. & Mfg. Co., Mansfield, O.

Vacuum Tubes.—Catalog, 56 pp. Describes types of Western Electric vacuum tubes for use by licensed amateurs in radio telephone transmitting equipments. In all, twenty-seven tubes are described, running from the smallest, or "peanut" tube to the 276A which has a maximum plate dissipation of 100 watts. Two pages in the catalog are devoted to the information on each tube. The information consists of a statement of the uses of the tubes, a table of electrical characteristics; a line drawing showing the shape of the tube, its internal structure and its outside dimensions; a diagram indicating where the various leads appear in the base prongs or other connections, and the code numbers of the sockets with which the tube may be used; in short, all data required by the amateur for designing his circuits in a radio telephone transmitting equipment is presented. Copies of the catalog may be obtained by licensed amateurs at the offices of the Graybar Electric Company which are located in 75 principal cities of the United States.